DISCOVERY

THE MAGAZINE OF SCIENTIFIC PROGRESS

FEBRUARY 1959 2/6

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CARRYING HER EGG-S

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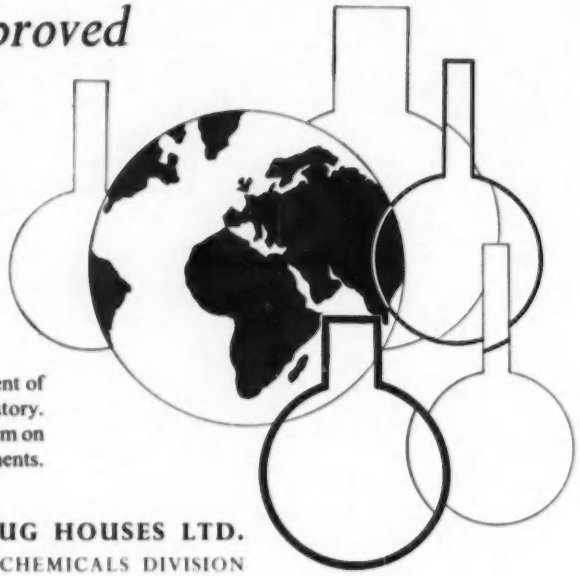

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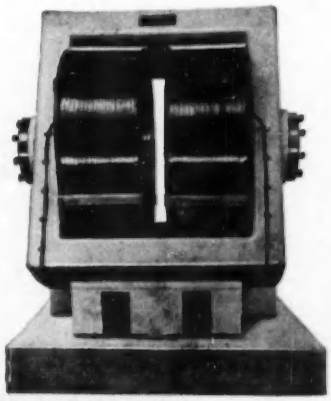

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Anthony R. Michaelis, PH.D., B.SC.

Editorial Office
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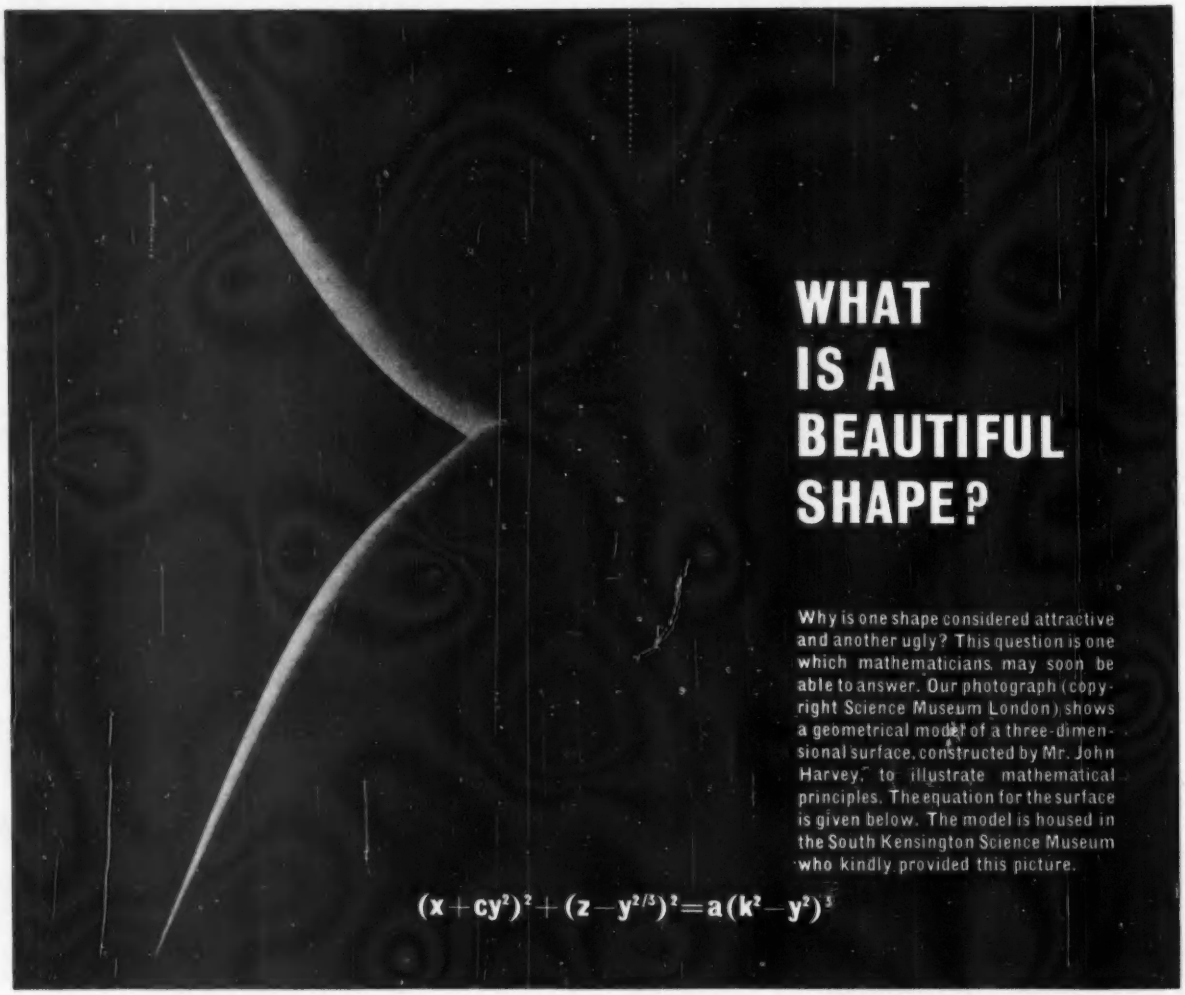
OUR COVER PICTURE

The female wolf-spider (*Pisaura mirabilis*) carrying her egg-sac in her jaws.
(See p. 52)



WHAT IS A BEAUTIFUL SHAPE?

Why is one shape considered attractive and another ugly? This question is one which mathematicians may soon be able to answer. Our photograph (copyright Science Museum London) shows a geometrical model of a three-dimensional surface, constructed by Mr. John Harvey, to illustrate mathematical principles. The equation for the surface is given below. The model is housed in the South Kensington Science Museum who kindly provided this picture.

$$(x+cy^2)^2+(z-y^{2/3})^2=a(k^2-y^2)^3$$

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THE SCIENTIFIC COMMONWEALTH

Although popular attention focuses on the Commonwealth as a political, military, and economic grouping, we must not ignore the unique contribution which, through a common language and common academic traditions and institutions, it can make to scientific progress, or the opportunity it provides for the successful application of science within its confines. This complex topic is not an easy field for summary examination. The range of disciplines in science are extensive; and the territories of the Commonwealth are far-flung and varied, not only in size and resources, but in the nature of their problems and their state of development: "primitive" colonial territories with some way to go towards nationhood, territories about to or having just gained independence, and nations with a standard of living equal to our own. Embracing all these are the wider questions—how far there is adequate scientific co-ordination in the Commonwealth and whether there is an effective policy for science as a whole.

Britain's immediate responsibility is in the colonial territories; here the need is greatest. Despite progress and the work of supranational agencies like the Scientific Council for Africa South of the Sahara, and the Technical Co-operation Scheme of the Colombo Plan, expenditure on research both as a proportion of national income and in relation to needs remains trivial, while the proportion of the population at school (a good index of educational achievement and scientific potential) is abysmally low. Admittedly, valuable projects have been sponsored through the Colonial Research Council out of Colonial Development and Welfare funds, amounting to £1·1 million last year; but total disbursements from these sources since the war at around the £13 million mark, apart from extra assistance from Colonial governments, surely indicates how much more must be done. Indeed, it is not surprising to find the Advisory Council on Scientific Policy commenting three years ago:

> ". . . the volume of research on problems affecting the Colonies was in many ways inadequate. . . . The number of scientists at present engaged in colonial research is about 450, which is little more than one-tenth of the number . . . employed by the DSIR and the Research Councils in the United Kingdom."

The claims on Britain to provide scientists for the Colonial Research Service and, more widely, to the colonial territories are likely to grow, and as these territories achieve independence the problem may become even more acute, since the indigenous governments may wish to concentrate their own efforts on applied research, thus leaving the more fundamental inquiries to international or Commonwealth action.

The picture for the self-governing members of the Commonwealth is different and, at first sight, better. Each country has its own research complex, not dissimilar to Britain's, and sustains an important scientific effort. Moreover, there is an efficient scientific liaison centre, the British Commonwealth Scientific Office in London, which provides a means for each Commonwealth country to draw on work done by another. However, the true extent of Commonwealth scientific co-operation, large as it is, cannot be measured through the formal work of this agency alone. Unquestionably, the major element is informal, either person to person, or institution to institution. But even in Canada, where the outlook is brightest, scientific effort appears to be running ahead of the supply of graduate students of engineering and those reading pure sciences. As for the territories which have recently reached independence, their need of overseas help with scientific manpower is already widely recognised.

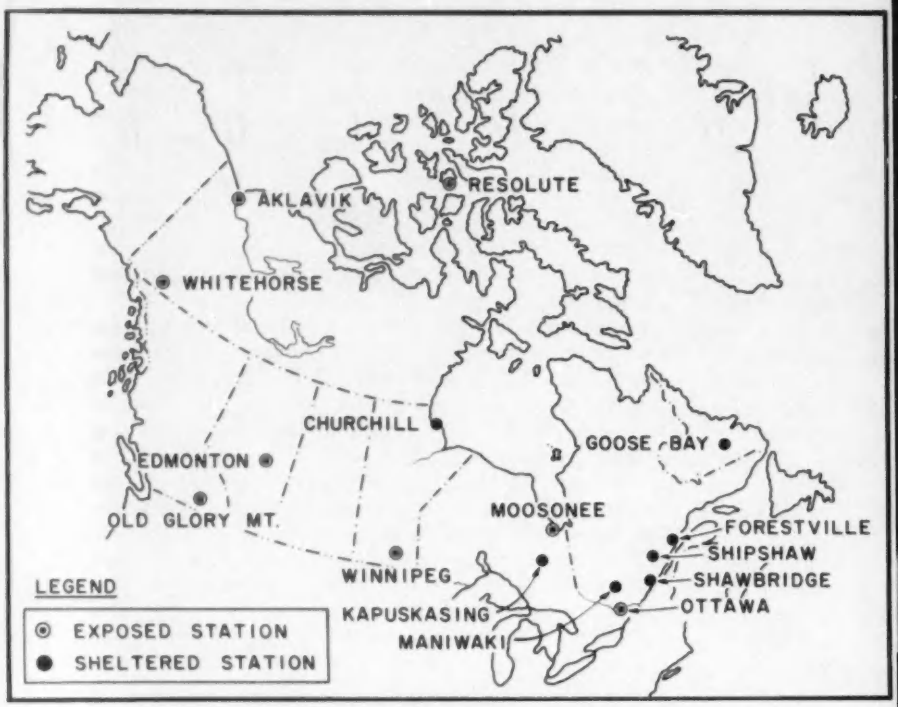
Inevitably, therefore, the question of Commonwealth scientific co-operation becomes a challenge. How far can it be developed as an instrument for scientific progress, as an associate for a more powerful economic effort, and as the means for the most effective use of English-speaking scientific manpower for which competing demand from the U.S.A. is likely to remain persistent, even growing? There are two views: a cautious and a bold one. The first inevitably lays greater stress on the evolution of the Commonwealth as an informal rather than a formal organism, and in the scientific field, questions the practicability of dispersing major projects between more than one country. Be that as it may, current economic problems and the pressure on scientific manpower may force us to the bolder view. It is depressing, therefore, to read the somewhat defeatist view in the latest report (1957–8) of the Advisory Council on Scientific Policy:

> "We consider that scientific manpower problems are primarily ones which individual countries have to solve for themselves, and that the scope for international co-operation in this field is bound to be limited."

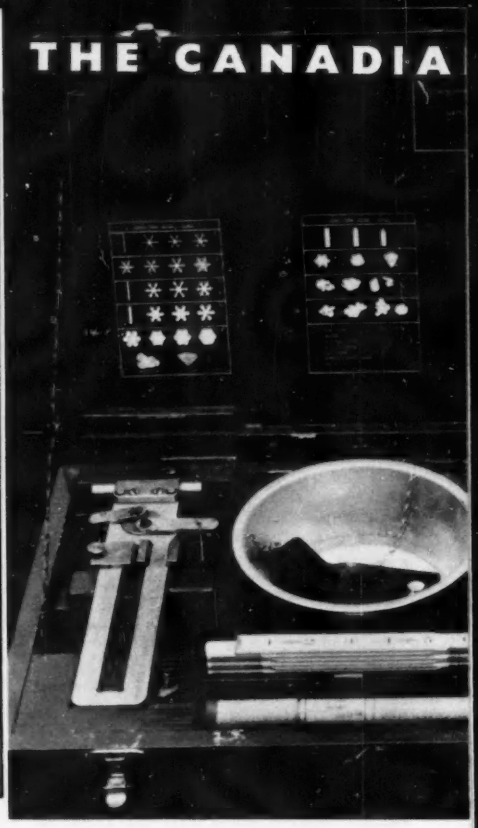
For effective progress we need the machinery and the right outlook. So far as machinery is concerned, the British Commonwealth Scientific Office, whose members are representatives of heads of National Research Centres, and meeting regularly, could, if strengthened, be an excellent nucleus for scientific policy-making; an exemplar is the considerable pooling of effort accomplished in the field of Commonwealth nuclear co-operation. As for outlook, the major obstacles have already been observed. Not only is there undue emphasis on national rather than broader planning which often makes Commonwealth scientific co-operation an exchange rather than the partnership it could be, but there is also the failure both on a national and Commonwealth basis to bring science directly into most policy matters when they are reviewed at the highest levels. In present circumstances any development of scientific co-operation in the Commonwealth would remain within an existing framework, not on a broader basis. For only through a radical change of perspectives can we speed the day of the scientific Commonwealth.

Important though the Scientific Commonwealth is, one issue is of vital urgency for the whole of mankind—The Internationalisation of Space, and of Space Research. Scientific and political leaders of all nations must now create the International Space Research Institute, and they must formulate a Law of Space; GOSPAR must become executive and not merely advisory. This issue is vital for the future of all mankind. ***Caelum Commune!***

THE CANADIA



Map showing location of snow survey stations in Canada.



The Associate Committee on Soil and Snow Mechanics initiated a snow survey in 1946 in recognition of the growing need for knowledge of the characteristics of the snow cover in Canada. It was hoped that this survey would satisfy the needs of those individuals, such as hydrologists and design engineers, who are faced with problems involving snow. To obtain an idea of the effect of snow on the Canadian economy one need only realise that much of the water in the storage basins utilised by hydro-electric installations is derived from winter precipitation, that much of the winter transport in unsettled areas is over virgin snow cover or compacted snow roads, and that the budget for clearing the snow from Canadian highways and cities runs to millions of dollars each year.

The instruments in the kit used in the snow survey were developed for the NRC by G. J. Klein of the Division of Mechanical Engineering during his studies on aircraft skis. The kit and forms on which the data could be recorded were distributed in the late autumn of 1946 to observers across Canada and were made available for the snow survey through the co-operation of the Meteorological Service of Canada and the Department of National Defence.

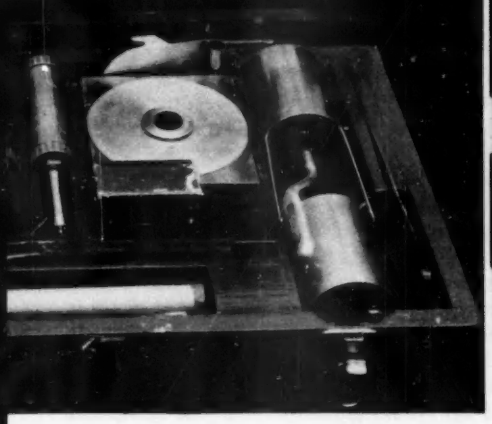
In his instruction manual Klein gives the following as the purpose of the snow tests: "The aim of the snow tests is to describe any particular snow-cover by means of measurements (or photographs) in order that the problems associated with it, such as snow performance of vehicles, skis, snow clearance equipment, and so forth, can be fully appreciated by the designers or users of such equipment."

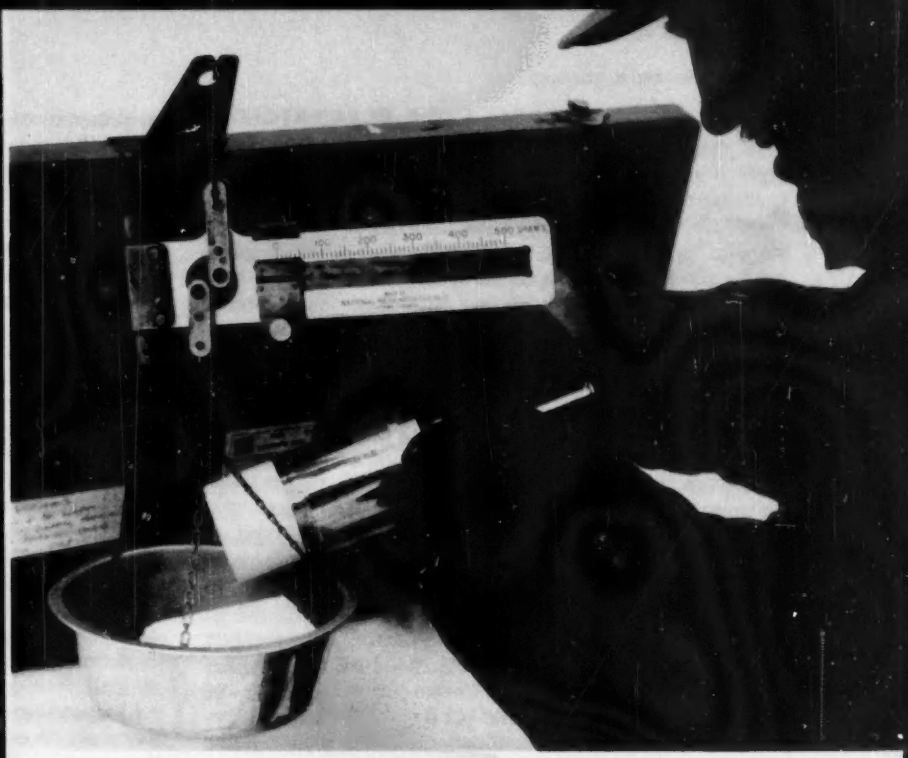
In 1948 Klein prepared a description of the survey which included the results of the first winter's observations. This was presented at the Oslo Conference of the International Union of Geodesy and Geophysics in 1948. At this conference a committee was organised with the specific task of preparing a snow classification which would be internationally acceptable. A tentative classification was prepared and was incorporated into the Canadian Snow Survey in 1949 and has been the basis for classification in the survey since that time.

In 1948, the Snow and Ice Section of the Canadian Division of Building Research was formed. Dr M. R. de Quervain was granted permission by the Swiss Government to leave his duties with the Swiss Federal Institute for Avalanche Control and spend one year (1948–9) with the National Research Council of Canada to evaluate snow and ice problems and to advise on the future development of research in Canada in this field.

In 1951 a more detailed summary was presented at the Brussels meeting of the International Union of Geodesy and Geophysics. The instructions on the taking and recording of observations were revised in 1950. The results to 1950 indicated that the survey had been somewhat restrictive as all observation stations were in exposed areas. This was remedied during the winter 1950–1 when some of the exposed stations were discontinued and sheltered stations initiated.

In the summer of 1955, a detailed analysis was made of the snow survey results. Up to this time all results had been reported on a station basis: the observations from each station were analysed and the results reported as being typical of that area. It was recognised that there were limitations to this approach. For example, results from many years of observations are required to establish a true average; it is not possible to evaluate local variations in snow cover from the limited data available; and





(*Left*) Snow instruments in container.

(*Above*) Weighing snow samples to determine density.

emphasising the snow properties in particular areas did not lend itself to prediction of snow properties at other sites. Some of the limitations were alleviated by slightly altering the original purpose of the snow survey. It was assumed that snow cover and its properties are the result of climatic factors. Instead of trying to establish the average snow conditions in specific areas, an attempt was made to correlate snow properties to the climate factors to which a specific snow cover had been subjected. From this point of view, observations for even one year (if they include certain meteorological elements) are significant. Furthermore, if correlations can be found, the vast amount of climatic data which has been gathered through the years now becomes available as a basis on which predictions can be made.

The results of the survey were analysed in 1955 from this point of view and the results proved to be encouraging. During the process of analysing the data, a further very useful purpose was realised: the experience of the past eight years became a basis on which a more comprehensive survey could be organised. Some of the factors which are to be considered in the future course of the survey are:

There is a natural gradation in the technical equipment and experience available at the observation sites; the survey should, therefore, be designed to complement the training and time available of the personnel responsible for making the observations.

In line with this, it was found that some properties of the snow cover were more important than others and therefore an order or priority was established; furthermore, it should be possible to simplify greatly the taking of observations in all cases, and particularly at sites where time and experience is a real factor.

The instruments required for making the observations on the snow cover can be modified to make them less expensive and more compact so that they will be more widely available.

One of the aspects of the survey which had been emphasised was individual snow layers and their properties. This developed from the experience of the Swiss who found that individual layers were important with respect to avalanches. By far the greater number of problems in Canada, however, involved the integrated properties of a snow cover, particularly the top 18 in. of that cover. Furthermore, the cover is usually involved in a direction normal to the surface whereas in the snow survey the measurements have been made in the direction parallel to the surface. Perhaps the only measurements which this affects are those which give the strength properties of the snow. Therefore, instead of taking the natural subdivision of the snow cover as the layer, it would be more convenient to measure the properties at fixed intervals. This approach has advantages when the data are analysed. Also, the survey may be greatly simplified if the more important observations could be made from the surface without digging a pit.

Taking observations at one site only in any area is not satisfactory. To get a better evaluation of the relation between snow cover and climate, more than one site should be used as long as the local conditions to which the site is subjected can be adequately described.

Some changes which have arisen from a consideration of these factors are being initiated at several of the observation stations. A programme of special observations on snowstorms has also been launched.

STORAGE—CINDERELLA OF ELECTRICITY

The "Cinderella" of electrical science is that branch which deals with the storage of energy: and yet the most vital problem facing the electrical engineer is to find means to "spread" his peak load, by using his expensive generating plant to fuller capacity at all times, instead of only operating for about one-sixth of its life at full load.

At present there are only two ways of storing electrical energy on anything like a commercial scale—pumped storage by water and storage by chemical methods, in accumulators of various kinds.

Pumped storage can only be employed on very large-scale static installations, where the lie of the land allows vast quantities of water to be pumped to a high reservoir during the night, in off-peak hours, to be released through turbines in the daytime, to take up the peak load. The nuclear stations of the future need to run at very nearly full output all the time, and pumped storage systems ought to be developed to a much greater extent than at present to make certain that the nuclear plants can be operated as economically as possible. There is in fact only one pumped storage plant in operation in Britain—in Scotland; one very large plant in the early stages of construction, in North Wales; and one other plant, in Scotland, in the planning stage. Many more plants should be planned, and whereas the topographical difficulties which prevent normal hydro-electric plants being envisaged in most parts of the British Isles are incontestable, it is very much easier to find sites where water could be pumped (even out of the sea) to reservoir areas two or three hundred feet higher and at a distance of not more than several hundred yards.

But there is no lack of research in the world as a whole into the design problems of pumped storage plants, where the pumps themselves follow closely the water turbine designs which nowadays are as efficient as it is possible to make them and which can be constructed on the largest scale ever likely to be needed.

It is in the field of electro-chemical storage where there is an unaccountable lack of progress. The basic forms of accumulator are the lead-acid and nickel-iron types, and while there have been improvements in ruggedness, service life and reliability, it is unfortunately true to say that for fifty years there has been no advance *in principle*. The basic limitations are the same as at the turn of the century: heavy weight per unit of output capacity, poor performance in low temperatures, and a high degree of maintenance are needed if even reasonably satisfactory service is to be expected. No battery can be recharged by any very rapid process—a vehicle battery, for example, such as those used in milk delivery trucks, if fully discharged can be injured, and if discharged to the safe limit needs several hours' recharging, under closely controlled conditions, if it is to continue to give reliable service. Nickel-iron or nickel-cadmium batteries can be short-circuited without damage, but lead-acid cells can be ruined by this accidental occurrence.

It is true that there are nowadays a number of special-purpose cells (for such uses as guided-missile power sources) which have very greatly improved characteristics in one particular direction, usually in the form of reduced weight and size, but at the expense of very short lives and great cost.

The zinc-silver oxide cell has made its appearance in the last few years, but only for special applications; and while it shows a distinct improvement on the lead-acid and nickel-iron cells in regard to storage capacity per lb. weight (having three times as much capacity) it has the same low performance at low temperatures and is costly.

What is needed is a form of storage cell which would enable an electric vehicle to become a serious competitor to the petrol-driven automobile. If this were possible, there would be a very large saving to a country like Britain, relying on imported oil for its vital road traffic. In addition, suitable night charging installations would bring greatly enhanced efficiency to the operation of the power stations.

A cell of the type suggested would need to be light enough to be handled easily by a garage attendant. Thus it would have to be about a quarter the weight of a conventional automobile battery at present: 10 lb. instead of 40 lb. It would need to store about ten times the energy the present car battery will hold; 600 ampere-hours instead of 60. It would have to have a higher voltage per cell, to reduce the current needed by the motors, say 10 volts instead of 2, as at present.

In very many forms of electrical engineering progress improvements of this order have been achieved. For example, aircraft dynamos and motors are twelve times smaller and lighter for a given output than before the war. Electronic components, of the sub-miniature type, are often made to be only one-twentieth of the size, for a given performance, of their predecessors of the immediate post-war era. Very large power-generators are just under half as large as they were in 1938. With a few exceptions for special purposes, the storage battery has stood still.

It is time a major programme of research into new methods of storing energy was instituted. Success in this field could have incredibly large dividends to pay and could appreciably strengthen our national energy resources.

PHOTOGRAPHY AND THE UNIVERSITIES

Photography is undoubtedly the only section of modern technology not yet represented in our universities. Whilst the chemists and physicists of the last century invented photography, their present-day successors have, perhaps, carried perfection too far. Anybody can now obtain a record of some sort by operating the camera shutter-release and letting the local chemist or a laboratory technician do the rest. This astonishingly unscientific attitude is only too common amongst scientists today.

It is accepted as a matter of course that some knowledge of electricity is desirable for those who use electronic apparatus in their work. Yet how many research workers will admit that the full exploitation of the numerous photographic techniques cannot be realised without a proper appreciation of the theory of the photographic process? Quite recently there was a two-day conference, at one of the big teaching hospitals in London, on "The Tools in Biological Research". This was thought sufficiently unique and important to arrange for the publication of these lectures in book form through Blackwell Scientific Publications, Oxford. Although electron microscopy was fully discussed, photography, without which electron microscopy could hardly be practised, was not considered at all.

It is almost a commonplace to say that autoradiography, radiography, and high-speed cinematography, to mention

only a few techniques, do not only provide convenient permanent records for publications and lectures, but that they are also a powerful medium for measurement and analysis. The effect of invisible radiation—gamma, roentgen, ultra-violet, and infra-red rays—can be made visible, and compared and measured on the photographic emulsion. Furthermore, the educated are familiar with the fact that phenomena and events which are too large or too small in size, or too slow or too fast in their development or movement to be appreciated by the unaided eye, can be brought within the range of scientific investigation through records obtained with photographic equipment. However, this general knowledge is of little avail and merely tantalising when the scientist finds himself in a situation where he suspects that photography might help him.

The problem might be considered as three-fold. Photography itself is not devoid of unsolved fundamental problems worthy of study at university level. Further advances in the manufacture of sensitive materials and recording apparatus, no less than the basic study of photographic methods and applications in teaching and research, must depend on an adequate supply of graduates who can combine a thorough knowledge of photographic theory and practice with an appreciation of the requirements peculiar to other disciplines. All this is by no means a revolutionary proposition. Since World War II Cornell University in the United States of America and the Eidgenössische Technische Hochschule at the University of Zürich in Switzerland have instituted courses in photographic science which count towards a university degree. Without wishing to present an exhaustive survey, the Institute for Scientific Films in Göttingen, which incidentally serves all the universities of the German Federal Republic, holds annual conferences and courses for university lecturers; the University Film Institute in Moscow should be mentioned as an indication that some countries are not insensible to the need for organised photographic training, study, and assistance within the universities. Even comparatively small countries like the Netherlands and Uruguay have found it worth while to endow university film institutes.

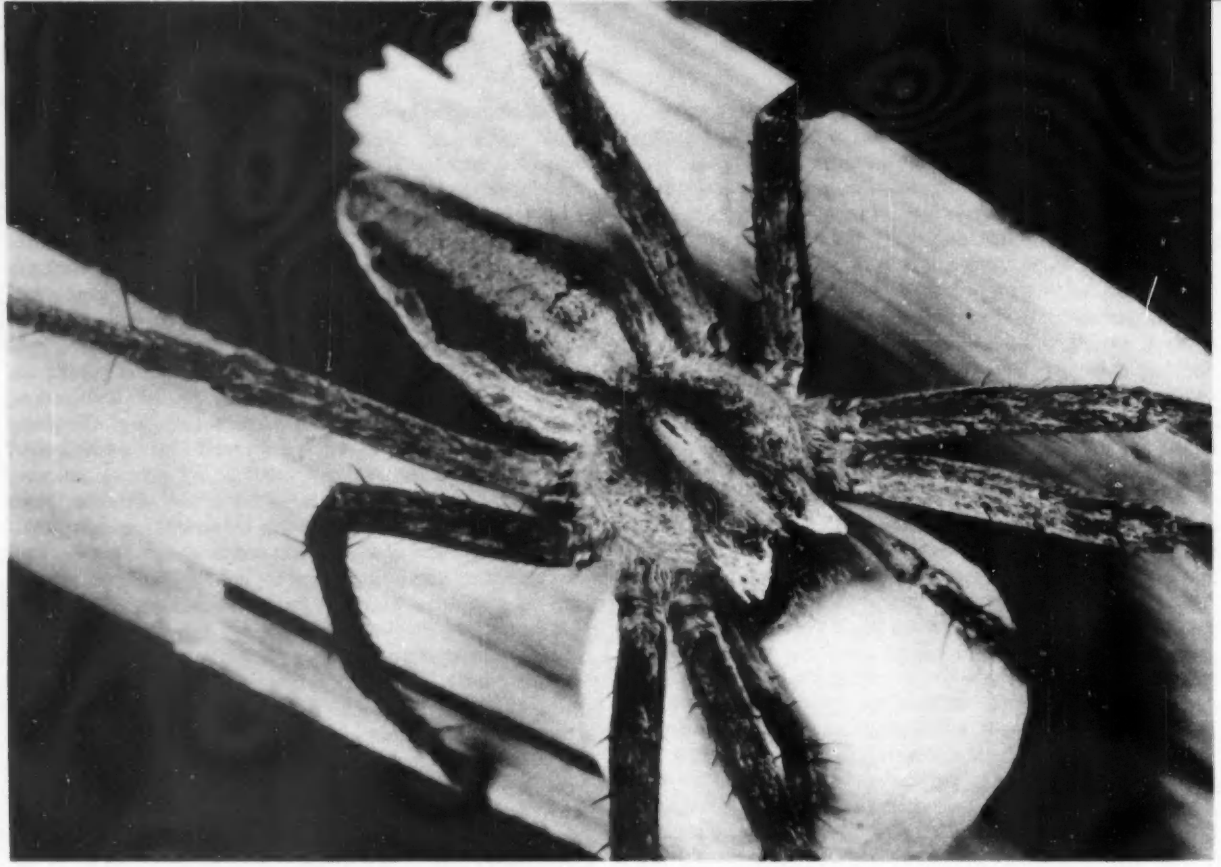
Although Great Britain has a number of Institutes of Education, apart from the somewhat theoretical work of Meredith, nothing comparable with the extensive experiments on visual aids in teaching by Carpenter and Greenhill at Pennsylvania State University in the United States of America has been attempted in this country. Various societies and organisations have tried to establish a readership in photography, but so far without success. For some time now the British Universities Film Council has planned towards the formation of a university film institute, but academic response has been similarly uncomprehending and unenthusiastic. This lack of vision and appreciation of the advantages which accrue by clothing photography with the academic gown should not be blamed solely on the vice-chancellors and the Treasury. The photographic industry in this country does not appear willing to learn from the conspicuous generosity of their eminently successful rivals in Germany and in the United States of America.

Apart from this recognition of photography as a university subject, ways and means should be found to offer basic instruction to science graduates, and possibly even to undergraduates, to enable them to make the best possible use of photography as an ancillary tool in their specialised fields of study. Once again, this need has not been neglected abroad. The professor of Optics in Medicine at the University of Hamburg has established a course of lectures on photographic theory and on practical applications as part of the *Studium generale* which sets out to acquaint graduates with the tools and method of investigation used in the natural sciences. Since his new appointment to the University of Munich he has started to organise a similar course in Munich. The Hamburg lectures have been published as a book. On the other side of the ocean, photography is firmly established at several universities. In this country the position is less encouraging. Only one or two medical schools offer a severely limited number of lectures on the general implications of photography in medicine, and the Imperial College of Science gives facilities for a short course on microscopy and photomicrography. Perhaps the lectures on the properties and application of the film in teaching and research, which the CIBA Foundation and the medical section of the Scientific Film Association have arranged for this winter, may be taken as an encouraging sign that private initiative may yet shame the universities into action. For surely it is high time that scientists were given an opportunity to familiarise themselves with this potent tool for recording and research.

Lastly, serious thought should be given to the creation of a journal which will present current advances in photographic instrumentation as well as new techniques and applications from all branches of science. There can be little doubt that such a publication would be of material help in many teaching departments and research laboratories. New developments in the manufacture of emulsions and apparatus as well as new techniques would quickly find their application if only they were readily available to those who can put them to good use. The few good books which do exist, like "Photographic Science" by Baines (Fountain Press) and "Research Film" by Michaelis (Academic Press), cannot be expected to remain up to date for very long in a field which is characterised by constant and rapid expansion. *Medical and Biological Illustration* (British Medical Association), a quarterly publication, attempts to fill this gap for the medical and biological sciences through its original articles and classified abstracts from the world literature. This should be regarded as but a brave beginning. The real need is for a journal which will appeal to workers in all the sciences.

Although three separate problems have been considered, they are really intimately linked and interdependent. Photography must be studied at university level. We will then obtain graduates who can conduct further research into the basic problems of photography, who can advance photographic instrumentation and technique, and who can instruct workers in other sciences in the most advantageous application of photography. These graduates will also be able to organise and administer university institutes of photography and cinematography. Finally, from amongst them would come the authors of new textbooks and the editors of a new journal on photography applied to science.

Wishful thinking, perhaps, but an absolute necessity if future generations are not to accuse us of wasting one of the most versatile tools of 20th-century technology.



Photograph shows wolf-spider carrying her egg-sac.

MATERNAL INSTINCTS IN WOLF-SPIDERS

Spiders are fierce, predatory animals always ready to kill and devour insects smaller than themselves. Nor do they refrain from cannibalism if the opportunity arises: violent battles ensue if a well-matched pair is confined so that they cannot escape. If the contestants are not well matched, the result is pure murder. Yet, as though to offset their aggressive and unsociable behaviour, many species are endowed with pronounced maternal instincts.

Amongst the aptly named wolf-spiders, long-sighted hunters who do not employ webs to ensnare their prey but chase and overcome it by sheer strength, the female carries her egg-sac about with her until the young have hatched. The baby spiderlings ride on their mother's back the first few days of their lives, but before long they scatter and disperse, for they are greedy creatures. Until mating time comes round they will not again approach one another except with hostile intent.

In most species, the egg-sac, or cocoon, is attached to the spinnerets of the female spider, but the female *Pisaura mirabilis* grasps it with her jaws. When the young are ready to emerge, she fixes it to the end of a twig and mounts guard over it.

The cocoon is a rather flattened sphere with an equatorial line around it, giving the effect of two valves. A circular cushion of silk is first constructed and the eggs deposited in the centre. The edges of the cushion are then gathered up, pulled over the eggs, and the bag thus formed is thickened with an external layer of silk on the two halves of the sphere, a seam being left at the equator for the eventual exit of the young spiders.

Removal of the cocoon is strongly resisted by the mother spider, who will search for it in all directions after it has been taken away. Although the prey is hunted by sight, the mother wolf-spider recognises an egg-sac by feeling it with the sensory appendages known as "pedipalps". The cocoon of another spider, even of a different species, is accepted with alacrity, provided that it is not greatly dissimilar in size.

One spider even accepted a cocoon in which a leaden shot had been inserted, making it many times its original weight. She could hardly crawl under the burden, but stuck to it gallantly, and when several attempts had failed to secure it to her spinnerets she carried it about between her jaws and the third pair of legs.

The intelligence of the spider is distinctly limited, but its powerful instincts are equal to all ordinary requirements. Their limitations are usually made apparent only by inquisitive human interference.

THE MILLIPEDE WITH 700 LEGS

An animal with 700 legs has recently been found in a Panama valley by H. F. Loomis, former Department of Agriculture, of Miami, Fla. (U.S.A.). It is a member of the millipede, or "thousand-legs", class of invertebrates, somewhat misnamed because no species yet known actually has a thousand legs.

It is a wormlike animal whose abode is under stones or rotting logs. Its body consists of 175 segments, strung one

after another. Each segment has a certain degree of independence, although various ones show some specialisation of function. The head segment, for example, is most richly endowed with nerves, it is probably the site of whatever consciousness the creature possesses, and is the forerunner of the "brain" at higher stages of evolution. Each segment has four legs and each set is more or less capable of acting independently.

On Barro Colorado island, the Smithsonian Institution's tropical-life preserve in the Canal Zone, Mr Loomis, one of the foremost American authorities on this group, also found some tiny white specks under rotting logs which looked like very small medicinal pills. More than twenty years ago he first discovered one of these "pills" and recognised it as a member of a new family of the millipede group, with only 20 segments and 80 legs, which is capable of rolling itself into a very tight ball. He has been seeking other specimens ever since This quest was one object of his work on Barro Colorado. It was successful, and a description of the new family will be published shortly.

Apart from many differences in structure, millipedes are unlike centipedes, Mr Loomis says, in that they live entirely on vegetable material while the other creature is entirely carnivorous. Favourite food of the millipedes is decaying vegetable-matter. Favourite food of the centipedes is small insects and lower forms of animal life.

Unlike the centipedes, millipedes are reputed to be non-poisonous. However, this is a mistaken idea. Apparently there is a poison gland in most segments from which a few of the "bugs" are able to shoot a highly caustic substance of some kind. They are also able to co-ordinate the action of all these glands, so that a fanlike spray of poison comes from the whole body. Mr Loomis himself got in the way of such a spray and, as a result, he was temporarily blinded in one eye and one side of his face was temporarily paralysed. The poison spray, he points out, must be intended purely for defence. The millipede is one of the least aggressive of animals.

"FRONTIERS OF SCIENCE", BRUSSELS

Only the Atomium is now left standing in the Royal Park at Belvedere as a symbol of the largest international fair and a reminder that science and technology in the peaceful service of man attracted some 42 million visitors to those Brussels grounds during six months in 1958.

How did science itself fare during that period? Very well, is the view of M. Jean Rasse, director of the International Science Hall at the Brussels Exhibition. No less than 5% of all visitors walked through his Hall.

What was the impact on them of what they saw there? This is a most difficult question to answer. The visitors were plunged straightway into "pure science", into the pioneer work being carried out on the frontiers of science. And there was no historical approach to enable them to see the exhibits in perspective. "The visitor may well be bewildered by the many exhibits", wrote Sir Lawrence Bragg. "If one wished to understand the significance of every exhibit, weeks could be spent in going round the Hall."

But there was some permanent effect on the Belgian Government. For the Belgians are now considering the establishment of a national science museum, something along the lines of the science museum in South Kensington.

They would prefer to have a permanent international exhibition, having as its theme "The Frontiers of Science". Requests have gone, therefore, to all the Governments who have exhibited in the International Science Hall for permanent collaboration along lines laid down during the Exhibition.

UNESCO is also involved, and influential key officials have expressed willingness to lend support for a scheme for an international science hall. OEEC, represented by Dr Alexander King, had already pressed for the present exhibition to be maintained for at least another two years.

Whatever the final form of a Brussels science museum, it will not be in the site at the Exhibition. A new and more central hall is to be found. Whether the cost will be borne entirely by the Belgian Government if it is to be international is not yet determined.

But certainly this is a scheme that merits sympathetic consideration. A permanent international "Frontiers of Science" exhibition would show clearly the nationally interdependent nature of scientific research. It would be unique in Europe—probably in the world.

CRUCIAL EXPERIMENT WITH CERN 600 MeV SYNCHRO-CYCLOTRON

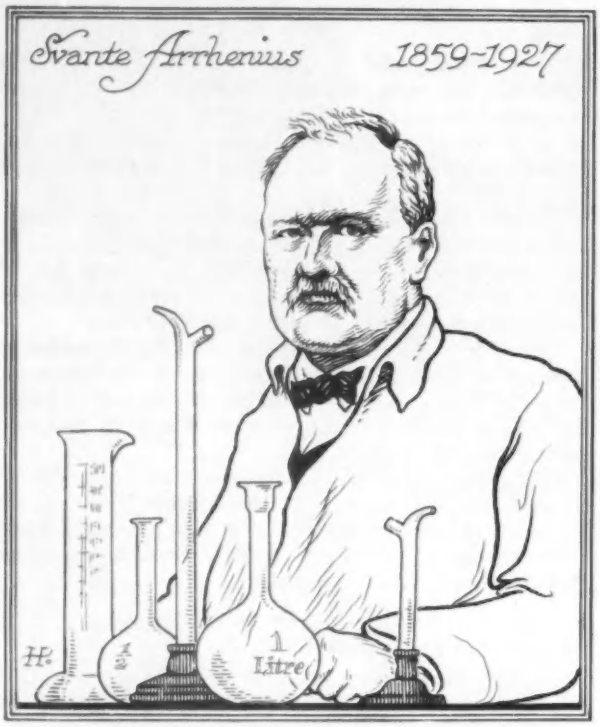
The CERN 600 MeV synchro-cyclotron has just made its first major contribution to nuclear physics. The two high-energy machines at CERN (see DISCOVERY, 1957, vol. 18, No. 11, p. 460), one of which is still under construction, have been built specifically to study the properties and interactions of so called elementary particles. One of these particles, the π-meson, was discovered in cosmic radiation about eleven years ago. It was observed then that it decayed in a very short time (about 10^{-8} sec.) into a μ-meson. The μ-meson itself decays in a rather longer time (about 10^{-6} sec.) into an electron.

Not long after the discovery of the π-meson it was predicted on very simple and straightforward theoretical grounds that every so often the π-meson should decay, not into a μ-meson but directly into an electron, and that this should occur once in every 10,000 decays (1 in 10^4). Experiments were performed at the Universities of Columbia and Chicago to look for these rare decays. The process was not observed, and it was concluded that if it occurred at all it must be less than 1 in 100,000 (1 in 10^5).

The discovery, two years ago, that parity was not conserved in certain processes in nuclear physics (see DISCOVERY, 1957, vol. 18, No. 4, p. 138) produced a very great simplification of our understanding of these phenomena. But there were still one or two major difficulties left, and one of the most serious of these was the negative result concerning the electron decay of the pion.

This inspired several groups of physicists throughout the world to search once more for the process, and one of these groups at CERN has been successful. They have demonstrated that this decay does occur, possibly with about the expected frequency. This has certainly eliminated a crucial difficulty for the theorists.

The group responsible for this experiment at CERN illustrates very well the essentially international character of the CERN laboratory. The group was made up of T. Fazzini (Italy), G. Fidecaro (Italy), A. W. Merrison (U.K.), H. Paul (Austria), and A. V. Tollestrup (U.S.A.).



A portrait of Arrhenius, specially drawn for DISCOVERY by Frank Horrabin.

ARRHENIUS—FATHER OF IONISATION

Although every student of science meets with the classical theory of electrolytic dissociation in solution, very few hear anything of Svante Arrhenius as the discoverer or founder of this basic principle in chemistry. Yet Arrhenius, born 100 years ago on February 19, provides a striking example of a scientist scoffed at simply because he introduced novel ideas unacceptable to the staid professors of his day. When he presented his thesis on this foundation stone of electrochemistry the board of examiners at Upsala University awarded him a fourth-class degree for the dissertation, while professors in other universities ignored copies sent them for discussion. The young chemist was regarded by the Swedish university board as "a stupid schoolboy". Upsala, which had produced a Berzelius and a Bergman, was in the doldrums in the period in which Arrhenius proved a worthy successor to Faraday in extending the study of salts in solution.

Arrhenius came from a farming family and certainly seemed of moderate ability as a student at Upsala. If he did not prove such a headache to the authorities as did Peter Griess and one or two other eminent chemists, Arrhenius was lively enough to become president of the Aurora Club with meetings which never broke up before dawn. In face of this seemingly poor start, the young chemist had the stroke of genius to visualise that Faraday's "ions"—electrically charged atoms or radicles—already existed in solutions before a current was passed. Faraday and Clausius had studied this problem of some solutions proving good conductors while other dissolved substances imparted no conductivity to a solution. But the idea of ions existing as separate parts formed from dissociation of molecules was too fantastic to scientists of that period. It had been ignored that if a current caused dissociation when applied to a solution, then energy would be consumed in such decompositions and evidence for such energy being absorbed should be noted.

Arrhenius followed up his idea of free ions by proposing that solutions acquired a high or low conductivity according to the degree of dissociation of the acid, base, or salt into ions—a weakly ionised electrolyte becoming more ionised as the dilution was increased. He postulated further that the speed of such ions as H^+ in the case of acid solutions as well as the numbers of ions would determine the conducting of a current. It was in the first volume of the *Zeitschrift* in 1887 that Arrhenius published his first account of "The Dissociation of Substances in Aqueous Solution", a paper which by a coincidence (or editorial design?) appeared next to one by van't Hoff on the analogy between solutions and gases. This led to a collaboration with van't Hoff which yielded the general theory of dilute solutions as we know it today, with ionisation explaining van't Hoff's anomalies found in studying osmotic pressures of solutions.

The new theory did not convince chemistry schools just as it almost caused Arrhenius to fail to graduate. Fortunately, a copy sent to Ostwald attracted his attention; Ostwald read the thesis and found it "difficult"; and so the eminent professor travelled to Upsala to seek out this unknown Swedish chemist. Such a visit from a maestro was the spark needed to set going a closer study, and Clève, the professor in charge at Upsala, gave Arrhenius a teaching post or *Privatdozent* in physics to keep him a year or so in Sweden. But then came the award of a travelling scholarship, which enabled Arrhenius to work for short periods with Ostwald, Kohlrausch, and van't Hoff. A coterie of "Ionians" was established, with Ostwald, van't Hoff, and Arrhenius the leaders, who had to fight vigorous criticism from other European chemistry schools. In 1890, however, matters came to a head at the British Association meeting at Leeds, where papers and discussions on the "Theory of Solutions" were on the agenda. Kelvin and Tilden were hostile to the "Ionians", with the celebrated Armstrong, or "H.E.A.", an unrelenting opponent up to his death. But Ramsay and James Walker were professors who gave support to Arrhenius, and the day was won. A year after the British Association meeting, Arrhenius was offered a chemistry chair at Giessen or Berlin—accounts vary; yet he preferred to take a lesser appointment in his native Sweden despite the poor reception given his doctrine.

A prophet without honour in his own country, Arrhenius was belatedly given a chemistry chair at Stockholm's Technical High School. But then came the honours, the Davy Medal in 1902, the Nobel Prize a year later, the Faraday Medal, and the invitation to give the Faraday Memorial Lecture at the Royal Institution in 1914. Arrhenius wrote works on electrochemistry as well as popular science texts such as "A World in the Making" and "Life of the Universe". But he will always be known as founder of the electrolytic dissociation theory which, with some modification in the case of "strong electrolytes", still stands as a memorial to a modest chemist who admitted his luck or fortune in that he began with dilute solutions "for which", he said, "the laws are simple".

AUSTRALIA'S PHYTOTRON

"A factory for man-made climates" was how Sir Ian Clunies Ross, Chairman of CSIRO, described the organisation's new phytotron at its Division of Plant Industry, Canberra, Australia. The phytotron will consist of a large number of cabinets in which plants can be grown under conditions in which the climatic variables which affect them can be controlled. It will enable scientists to tailor-make plants to suit specific regions infinitely more rapidly, precisely and economically than ever before.

The first phytotron, designed by Prof. Frits Went, was built at Pasadena, California, U.S.A. It consists of a group of more than fifty glass houses and artificially lighted rooms each maintained under a particular light and temperature régime. Other rooms permit the control of wind, rain, humidity, and atmospheric composition. The plants are grown on trolleys, which can be moved, either daily or at longer intervals from one room to another. In this way it is possible at any one time to expose plants to more than five hundred different, but reproducible and precisely known, climatic conditions. They can be subjected at will to winter cold or summer heat, to rain or sunshine, wind or fog.

The Canberra phytotron will have a radically new design. It will consist of more than two hundred cabinets each capable of operating over a wide range of climatic conditions. The plants will remain in the cabinets at all times, except for measurement or experimental operations. This design will give much greater flexibility than the Californian design.

Each cabinet will be 6 ft. by 3 ft. Most of them will work under natural light as part of a glass house divided into fifteen sections. Each section will contain eight cabinets with similar temperature régimes.

In the four central sections the cabinets will also condition the space around them, and this will be occupied by plants on trolleys which can be wheeled to the other enclosures or to the dark rooms opposite. The remaining cabinets will be artificially illuminated and will be enclosed in rooms in the body of the building.

There will also be special rooms for the control of atmospheric composition, frost, and humidity, as well as instrument control rooms, a laboratory, a preparation room, and a workshop for mechanical maintenance. CSIRO has already tested several cabinets which have been designed by its own staff.

Practically every plant which is of economic significance in Australian agriculture has been introduced, very often by chance, from its original home overseas. They have evolved in regions with climates and soils different from Australia and many are not particularly well adapted to the climatic stresses of their new home.

A great deal of ingenuity and hard work on the part of farmers and scientists over the last one hundred years has gone a long way towards adapting some of the crops to the Australian environment, and the environment to the requirements of the crops.

The wheat-breeding work of William Farrer and his successors is an example. This made the Australian wheat industry not only possible but also one of the most efficient in the world.

Unit cabinet for Australian phytotron, which is 6 ft. by 3 ft. in size. In this model, temperature can be controlled in range from 40° to 100°F to within 1 degree. Day length is controlled by automatic shutters and supplementary artificial lighting.

There are many other crops to be improved and adapted to Australian climates: perennial rye-grass for the New England region of New South Wales or for the Western District of Victoria; lucerne for grazing in lower-rainfall areas or for irrigation; subterranean clover for northern New South Wales or for drier districts beyond the reach of existing strains; legume crops for the sub-tropics and the tropics; field crops which have presented difficult problems but which may have a greatly enhanced future if only suitable varieties are found—soya beans, peanuts, cotton, and possibly rice in the north-west of the continent.

Work with any of these, and many more, can be lifted to new levels of precision, economy, and speed by the availability of controlled environment facilities. And some of it will be rendered possible only by access to a phytotron.

INTERNATIONAL SCIENTIFIC MEETINGS AND EXHIBITIONS

Science and Design

A small exhibition was recently held at the Council of Industrial Design's Centre in London which had as its aim the explanation of a method of design practice which is comparatively new in Great Britain. The work of the General Consultant Designer is at the same time highly specialised and diverse in character. It may be the design of a single object such as a light fitting or the package for a new cigarette, a major project such as the interior design of an aircraft or liner, or it may involve responsibility for the whole visual identity of a large industrial undertaking.

To be able to resolve so wide a range of design problems, the industrial designer must be an expert in at least one branch of design and have considerable knowledge and experience of many. He must above all be expert in collaborative working with specialist designers and with management. He requires not greater ability than that which characterises the specialist designer, but differently emphasised interests and experience in a wider field of practice.

The Consultant Designer works in different ways for different industries. He may have responsibility for every aspect of a company's design policy, from the product itself to the package which protects it; from the design of stationery to the livery of the transport fleet; from factory layout to the decoration of the chairman's dining-room; from the design of special furniture and equipment to that of illuminated signs.

Alternatively, he may be concerned only with the design of a range of engineering or other products, working in close association with the staff designers. In these circumstances he brings to one industry the experience gained in many and an understanding of the movements in public taste which is sometimes outside the experience of the specialist designer.

The panels in the exhibition demonstrated both aspects of the practice of the General Consultant Designer. Some showed the wide range of design commissions which together produce a house style or visual character for a company: others showed the diversity of practice of Consultant Designers, always achieved by their working in close association with their colleagues, their own staff, or with specialists in the design offices and research laboratories of their clients. A few examples of the effect of good design on scientific and technical objects are illustrated here.

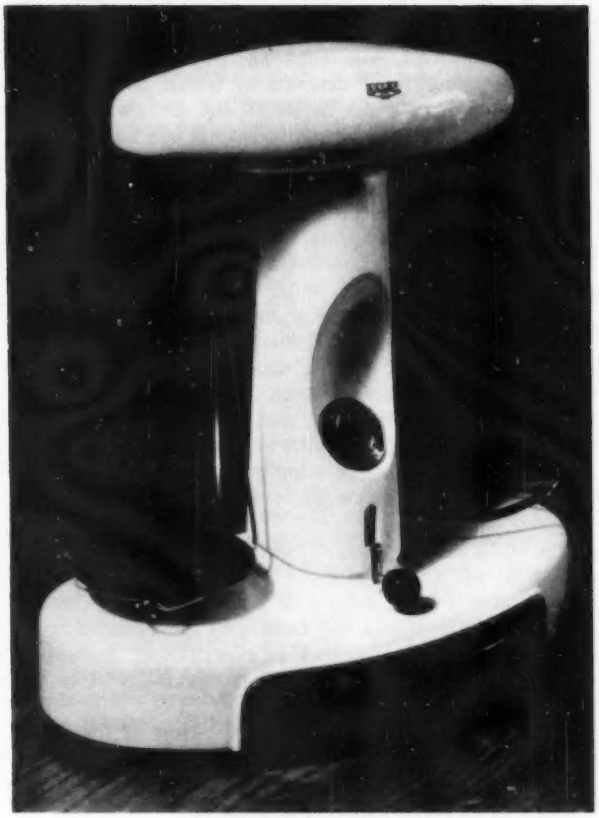


FIG. 1. A balance designed for W. & T. Avery Ltd, by John Barnes, F.S.I.A., of Allen-Bowden Ltd.

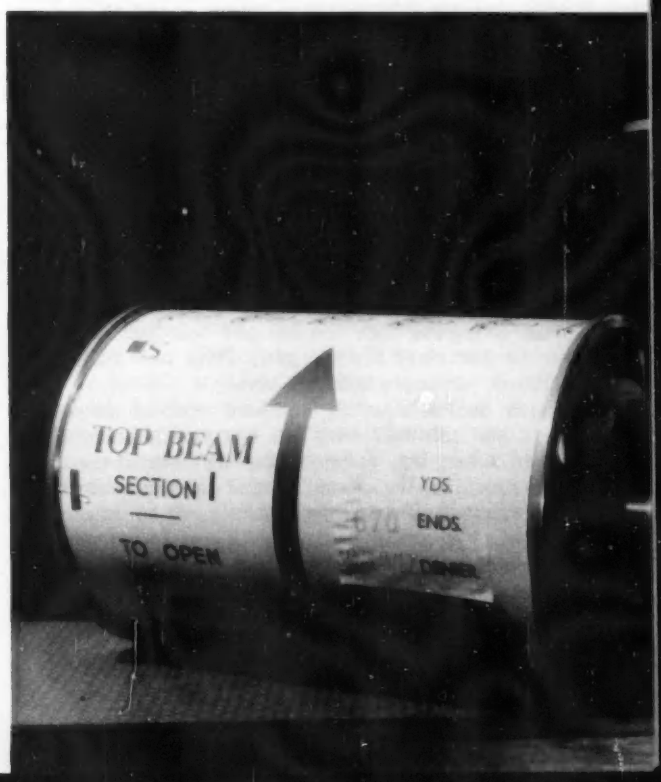


FIG. 5. (*Right*) Warp knit beam designed for British Nylon Spinners Ltd by J. Beresford Evans.

FIG. 2. A centrifuge designed for Hawksley & Sons Ltd, by John Barnes, F.S.I.A., of Allen-Bowden Ltd.

FIG. 3. A globe with new Perspex stand designed for Philips, by Robert Gutman, F.S.I.A.

FIG. 4. (*Right*) 2000 h.p. diesel hydraulic locomotive built by the North British Locomotive Co. Ltd for British Transport Commission. Body form designed by J. P. McCrum in collaboration with the engineers of the Company. Design Consultant to British Transport Commission: Misha Black, O.B.E., R.D.I., P.P.S.I.A., of Design Research Unit.

The outer skin has been designed for the use of aluminium alloys to save weight; the main body to be fabricated from sheet aluminium flush-riveted to frames; the cab and nose, with their compound curvatures, from light-section aluminium castings bolted together.

Space Medicine Symposium

During the period of the IGY there have been many spectacular achievements in the field of space research or astronautics; these achievements have involved the use of high-altitude rockets, artificial satellites, and lunar probes. This year we may even expect to read of the progress of probe rockets towards Mars and Venus. However, all this is but the prelude to a more important development—manned space flight, the main objective in both American and Russian space-research programmes. The satellite and probe-rocket experiments are essential preliminaries, for they both provide information about the conditions which will be encountered in space, and are steps towards the development of the larger and more reliable vehicles needed for manned flight.

Another necessary preliminary is to study how man himself will behave under extra-terrestrial conditions and to develop equipment needed to support life or provide a minimum degree of comfort. Intensive research has been proceeding in this subject for over ten years in the United States; there is less information available about developments in Russia, but the rocket and satellite experiments with dogs indicate that these problems are not being neglected. Britain still has no official space-flight programme and if one is established it is likely to be concerned mainly with satellites. The Space Medicine Symposium held on October 16–17 at BMA House, London, was therefore organised by the British Interplanetary Society to draw attention to the human factors of space flight. It was the first international symposium on this subject to have been held in Britain, although various aspects of space medicine have previously been dealt with in the Society's lectures and publications.

Five papers were presented by members of the staff of the RAF Institute of Aviation Medicine, Farnborough. Flight-Lieutenant J. C. Guignard discussed the various transient and fluctuating forces which would act on the crews during space flight, the effects of vibrations of different frequency, and the limits of human tolerance to acceleration. Take-off, ballistic flight, re-entry, and survival ejection each presents its own particular problems. Low-frequency vibrations in the range 1 to 100 cycles/sec. are a potential cause of discomfort and may well be aggravated by weightlessness. Flight-Lieutenant J. Billingham read two papers on heat exchange between man and his environment, during interplanetary travel and on the surface of the Moon respectively. Preliminary results in an experimental "hot cabin" have shown that a man can be protected against temperatures of 100°C in the cabin by air ventilation beneath his clothing. Such temperatures are likely to arise when the skin of the vehicle is subjected to aerodynamic heating during re-entry into the Earth's atmosphere. If re-entry lasts only ten minutes, it might even be possible to use Arctic clothing for insulation against the heat. On the lunar surface a space-suit incorporating aluminium foil insulation is desirable, but cooling would be necessary by night as well as by day, for although night surface temperatures are not greater than −150°C the heat loss from the suit is only one-tenth of the heat produced metabolically.

Squadron-Leader T. C. D. Whiteside dealt with vision and orientation at high altitudes. Dr K. F. Jackson was concerned with the problem of the impairment of human performance in the operation of control equipment. He reported the results of experimental investigations with aircraft pilots and demonstrated a portable, battery-operated instrument for assessing their performance.

Another contribution on man-machine systems came from Commander George W. Hoover of the U.S. Navy. The instrumentation programme he outlined was initially concerned with aircraft but was also of general application and was extended to all man-made vehicles: helicopters, missiles, submarines, tanks, surface-ships, and space-ships. A film showed the method which had been adopted to try to improve and simplify the relationship between man and machine. Instead of the multitude of dials and gauges that are a feature of, say, the aircraft cockpit, the information they normally register would be fed into a computer, which would then select the data necessary for control of the vehicle and feed appropriate signals to a cathode-ray screen to provide a visual display. For aircraft, information concerning orientation of the vehicle, horizon, flight path, local geography, position, targets, flight plan, fuel reserves, etc., could be integrated into the display; for a space-ship, the display might present a theoretical path from the Earth to the destination, with the flight path superimposed upon it.

Dr G. Pugh, of the Medical Research Council, talked about the effects of altitude on consciousness. As an Everest climber, he was able to do this from personal experience. The first astronauts might have to endure weightlessness, oxygen deficiency, lack of sleep, and poor diet, and these would lead to various mental disorders. Mr Cyril Cunningham, of the Air Ministry, discussed the probable effects of sensory impoverishment, confinement, and sleep deprivation, it being assumed that a space traveller would be alone, restricted in movement, mainly deprived of auditory and external visual stimuli and largely unaware of the vehicle's movement in space. He presented evidence obtained from isolation experiments in Canada, and from political prisoners who had endured solitary confinement for periods of up to seven years. From his own experience he thought it possible to train astronauts to stay awake for a few weeks.

Dr C. J. Clemedson of the Research Institute of National Defence, Stockholm drew attention to the similarities and dissimilarities in the biological effects caused by explosive decompression (which might result from the impact of comparatively large meteorites with the space-ship) and by blast. Dr M. P. Lansberg of the National Aeromedical Centre, Netherlands dealt with some consequences of weightlessness and of "artificial weight" produced by rotation of a satellite or rocket. Dr A. E. Slater reviewed recent information concerning the radiation belt surrounding the Earth. The problems of feeding during space voyages were discussed by Mr S. W. F. Hanson of the Ministry of Agriculture, Fisheries and Food. For short orbital flights, foods and equipment already developed for feeding aircraft pilots through oxygen masks could be adapted. For a lunar trip lasting a matter of days, dehydrated foods which could be reconstituted by the addition of hot water seemed to be the best solution, but for a journey lasting several months or years, it would probably be necessary to establish a closed biological cycle, with a microcosmic plant-animal balance.

The most provocative contribution came from Drs A. S. Parkes and Audrey Smith of the National Institute of Medical Research. When considering long interplanetary journeys, one sometimes thinks how convenient it would be if the astronaut could be put into a state of hibernation for most of the journey, by hypnosis or the administering of some yet-to-be-discovered drug. Parkes and Smith suggested that it might be possible to deep-freeze the travellers. The advantages are of course that food and air requirements would be reduced and that the boredom and other rigours of the journey could be minimised. It seems unlikely that such techniques will be applicable to man for at least many years to come.

Sociology of Roads

The International Road Federation, with its main offices in London, Paris, and Washington, but with affiliated organisations all over the world, is concerned more with the economics and the social justifications for road-building than with the technology as such. Naturally, however, technology has an effect on the economics, and traffic jams and bottlenecks are great wasters of money. So in the Third World Meeting of the Federation, held in Mexico City in October 1958, the subjects ranged widely, and a mass of information from over- and under-developed countries was collected and pooled. By the time this is sifted, the Federation should be in possession of material which could usefully be disseminated not only to road builders but to governments and financing bodies.

A sharp distinction was drawn at the Congress between the problems of highly industrialised and urbanised countries, and others such as Pakistan, the African countries, and Mexico itself, with much land still inaccessible except on foot or with pack-beast. Whereas the justification for more roads in already developed countries must be economic, and the problems are those of traffic control and distribution, in less developed countries roads carry with them sociological implications that are far-reaching. Campaigns to control infant mortality, to combat malaria, blackwater fever, locusts and other pests, can scarcely be carried out efficiently if there are no roads.

Roads driven into remote territories create a responsibility on the part of central governments towards unintegrated tribes that may have lived until recently untouched by western civilisation. Therefore it is important that any road-building programme should be co-ordinated with whatever educational and health schemes may exist. It was strangely disturbing, for instance, to notice that in the mountains of South Mexico the indigenous Indian villages that are still far from roads are more sober and more industrious than some that are now on the Pan-American Highway itself, whose inhabitants have already begun to rely on charity from tourists, an easy excuse for sloth. On the other hand the side roads leading up into the mountains have made it possible not only for schools and medical services to be extended but also for the administrators, doctors, nurses, and other social workers to live less isolated lives—a factor which undoubtedly helps to keep up their own morale and enthusiasm.

It is important in under-developed countries, too, that road-building should not outstrip the technical capacity of those who will use them. This applies to artisans and drivers more than to engineers, for it is usually in semi-skilled labour that under-developed countries are most deficient. In Mexico City there is a centre for training operators which is supposed to be almost unique in the world; there is one other in Istanbul. Interested firms in the United States have given equipment and funds, and here young men are trained in the use and maintenance of tractors and agricultural equipment of all kinds, and in diesel as well as petrol engines. Pupils come from Mexico itself, but also from South and Central America, and they can enter either for a fifteen-week operators' course (five weeks' theory and ten in the field) or for a sixty-week mechanics' course. The pupils are quickly absorbed in various branches of road-building and agricultural development. A school such as this, though it needs expensive and heavy equipment, is so easy to set up, and so practically useful in any country where roads are being built as part of a wider development plan, that it is surprising there are not similar ones elsewhere.

Moscow's International Astronomical Conference

The Tenth International Astronomical Congress was held in Moscow in 1958 and was attended by more than a thousand scientists from thirty-five countries. A variety of papers were given on all the different aspects of astronomical and solar observation.

A large amount of research has recently been done by Soviet observatories on solar activity and its influence on the Earth's atmosphere. As it is the circulation of the Earth's atmosphere which determines climate and weather conditions, great interest was shown in this report. It is now known that a cycle of solar activity covers a period of eighty to ninety years, thus it should now be possible to work out long-term weather and climatic conditions.

In another paper Prof. Simpson of Chicago University said that the connexion between bursts of cosmic radiation on the Sun and the propagation of light was erroneous. Cosmic rays originate on the Sun as well as in outer space, though how they start is still a mystery.

The Sun's surface was the subject of a paper by an American scientist, Prof. M. Schwarzschild, and Dr A. Dollfus of France. Prof. Schwarzschild has succeeded in taking 8000 photographs of the Sun's surface with the aid of a telescope suspended from a balloon. He used automatic controls for the camera and the instruments were controlled from the ground by radio.

Britain's leading astronomer, Fred Hoyle, gave a paper on a new theory on the formation of the planetary system. He said that when the Sun was still a giant gaseous sphere, exfoliation might have occurred due to a centrifugal force arising in its equatorial zone.

Most of the speakers, however, had one similar thought: the need for international co-operation, not only in astronomy but in all fields of science. They mentioned the success of the International Geophysical Year and the hope that the Moscow Astronomical Congress would be as fruitful.

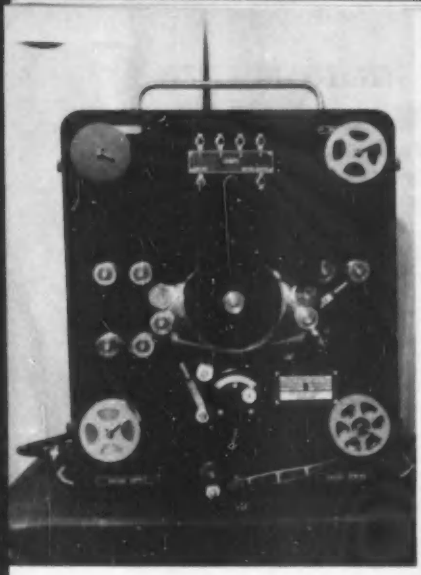


FIG. 1. (*Above*) Close-up of the Kalfax microfilm printer processor.

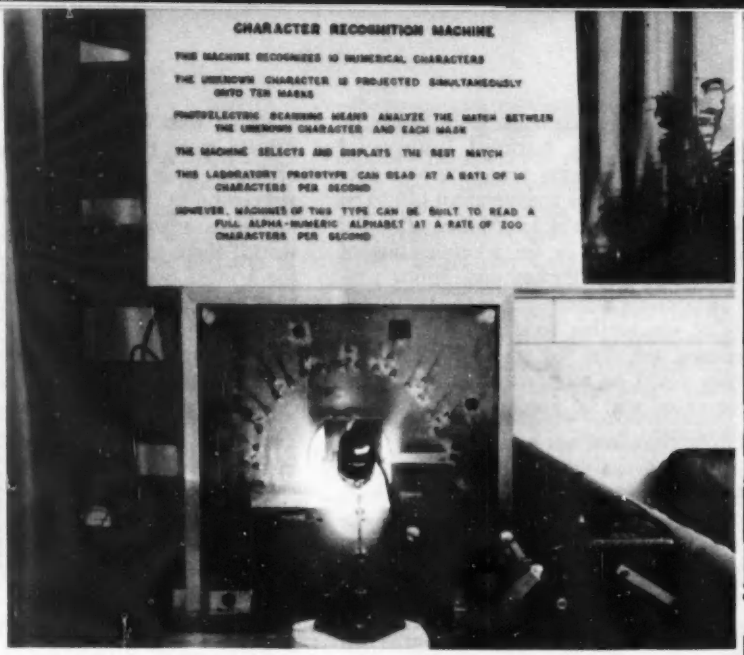

CHARACTER RECOGNITION MACHINE
THIS MACHINE RECOGNIZES 10 NUMERICAL CHARACTERS
THE UNKNOWN CHARACTER IS PROJECTED SIMULTANEOUSLY ONTO TEN MASKS
PHOTOELECTRIC SCANNING MEANS ANALYZE THE MATCH BETWEEN THE UNKNOWN CHARACTER AND EACH MASK
THE MACHINE SELECTS AND DISPLAYS THE BEST MATCH
THIS LABORATORY PROTOTYPE CAN READ AT A RATE OF 10 CHARACTERS PER SECOND
HOWEVER, MACHINES OF THIS TYPE CAN BE BUILT TO READ A FULL ALPHA-NUMERIC ALPHABET AT A RATE OF 200 CHARACTERS PER SECOND

FIG. 2. (*Above*) Close-up of character recognition machine.

FIG. 3. (*Right*) Close-up of high-speed analogue to digital converter.

Scientific Information Conference

Today the problems of storing the vast amount of scientific information which is published, and efficiently retrieving any item required, are taxing the minds of scientists, librarians, and information officers. In 1948 the Royal Society held a conference covering the whole field of scientific information, and now, ten years later, the United States National Science Foundation, National Academy of Sciences, and American Institute of Documentation, have held an International Conference on Scientific Information in Washington, D.C. Concerned with storage and retrieval problems, the Conference was attended by about 1000 delegates and, for convenience, was arranged in seven sections or "areas". Area (I) dealt with the information needs of scientists, (II) with abstracting, and (III) with monographs, compendia, and specialised information centres. Areas (IV), (V), and (VI) were concerned with the organisation of information for storage and retrieval, and, finally, area (VII), with the responsibility for information services of government, industry, universities, and learned societies.

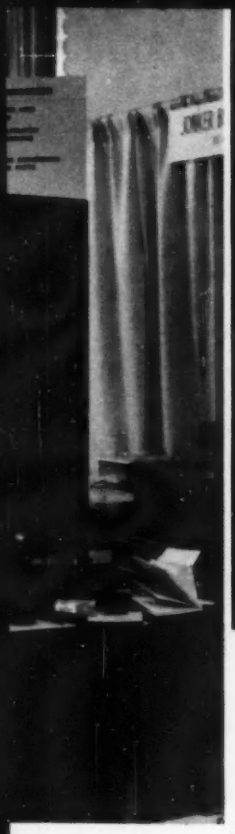
The Conference began on a Sunday evening with speeches of welcome from, among others, Dr Detlev Bronk (President of the National Academy of Sciences) and Dr Wallace Atwood, Jnr. (Foreign Secretary of the Academy and Chairman of the Conference Committee), while Sir Lindor Brown (Biological Secretary of the Royal Society) gave the Conference address. It is probably true to say that this address set the seal upon the discussions of the next six days, for Sir Lindor stressed important factors often overlooked and, in fact, struck at the very heart of the "information problem". He first raised the question of *quantity*, and queried the need for much scientific literature at present produced, expressing the hope that scientists would exercise some self-restraint in making known their work and publish once and once only. Secondly, Sir Lindor dealt with the problem of *quality*, and made the bold suggestion that there should be some selection between good and bad scientific papers—while admitting that the information officer might want to extract "the uncut gems" buried in bad papers and polish them, he suggested that the scientist would not have the time to gaze on the results and exhorted scientists and information officers to consider together some practical means for selection.

The Conference was arranged so that the panel members of each area either discussed the papers which had been presented or the subject-matter as they saw it. Time was afterwards given for authors and panel members of other areas to take part. The papers, 1420 pages in all, printed and circulated before the Conference, were intended to form the basis for discussion.

The needs of scientists and reviews of their reading habits were the first subjects dealt with. As is known, rates of reading and assimilating information vary (figures of between 2·5 and 9·8 words per second were quoted), and a plea was made for research on the physiology and psychology of this question. The ephemeral nature of some publications compared with the permanent value of others was stressed.

Abstracting was next considered. There seemed to be a division of opinion as to whether abstracts or an abstract/index system were required, but a defence was made of the specialised abstract.

The session on monographs, compendia, and specialised information centres resulted in a very general discussion. The expansion of "information" (predicted at the Royal Society Conference ten years earlier) and the failure of



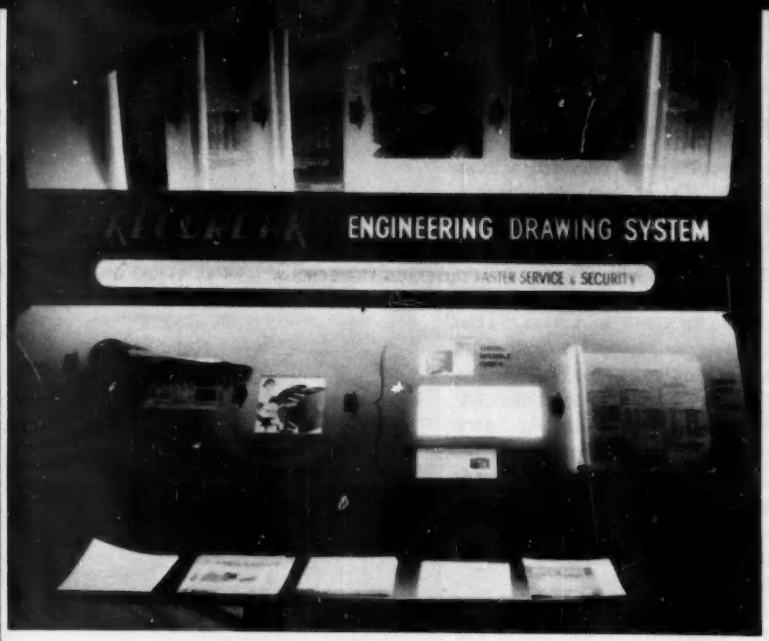


FIG. 4. (*Above*) Recordak display of engineering drawing microfilm system—the spectrophotometric system also uses cards with microfilm inserts.

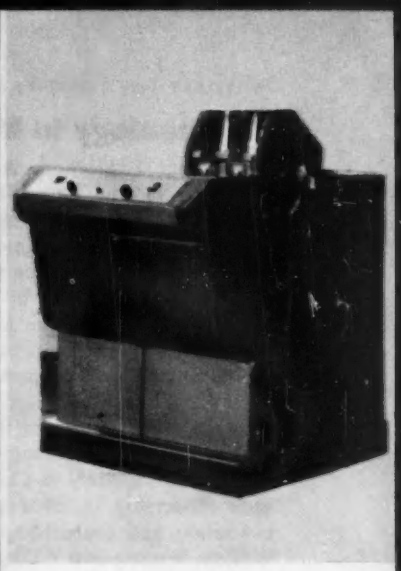


FIG. 5. (*Above*) Recordak Listomatic camera.

information services to deal with it was stressed and a call for more reviews was made, although opinion differed on what type of reviews would best serve the scientist. It was also suggested that reviews should be written by two authors, a younger scientist doing the literature research and a more experienced colleague writing the critical approach. Russian experiments on producing monographs and assessing their use were mentioned, but no agreement was reached on centralisation or decentralisation of information centres.

Computers, "information language", and mathematical retrieval theory came in for much discussion. Although, obviously, much development lay ahead, it seemed agreed that a machine was primarily a mechanised clerk; the intellectual problems remained. The tackling of one specific field of science was suggested as a practical step and hope was expressed for development of general theorems on retrieval theory.

An "extra-mural" demonstration of a machine providing Russian translations of papers in physical chemistry was given, and many interesting devices were on display in an exhibition attached to the Conference. Recordak showed not only microfilming equipment but also the Listomatic camera which takes cards, automatically arranges them for photographing, and then does so, and a method of using coded film for spectrophotometric data. Some other exhibitors also showed coded film for storage and retrieval; the Ranibow Engineering Co. showed a surprisingly small "character" recognition device which could "read" digits, and IBM punched-card devices were also in evidence. This Company also arranged visits to the Vanguard computing centre. The new Besseler-Kalvar film, which requires only a brief and simple heat-treatment for processing after exposure to light of mainly ultra-violet wavelengths, attracted much attention, as well as the Kalfax microfilm printer/processor, which makes, in full daylight, positives of 16-mm. or 35-mm. negative microfilm at a rate of 20 ft. a minute. Also on display for the first time was the Kodak Minicard equipment; an automated automation of micro-microfilm which leaves one with a feeling that the engineer may be in danger of evolving electronic steam-hammers for cracking information nuts!

In the section on responsibility for information services the vital role of scientific societies as publishers of quality papers was stressed and the issue of information by off-prints raised. It was clear that abstracting needed financial support, and the successful work of the ICSU Abstracting Board in arranging co-operation on an international scale was reported. No agreement was reached on "international information centres", but there was no doubt about the necessity of providing adequate finances for information activities.

In accordance with the wishes of the organisers, no recommendations or resolutions were made at the final session of the conference. It was, however, clear to everyone that too much information is produced and there was a general feeling that some selective procedure must be evolved.

In spite of the absence of formal resolutions the Conference was worth while. The problems of retrieval and storage received an airing, and, equally important, delegates were able to meet and discuss together the pressing problems of scientific information. Dr Atwood himself admirably summed up the proceedings with the quotation "it is better to have travelled hopefully than to have arrived".

Archaeology in Modern China

The recent Exhibition, Archaeology in Modern China, organised by the Britain-China Friendship Association, indicates a very positive step towards what one hopes will be the increased exchange of information between Chinese and European archaeologists. The exhibition consists of about 150 photographs of archaeological finds excavated and discovered over the last eight years in China. That such an exhibition was urgently needed becomes clear from the fact that information on archaeological work in China during the last decade has been restricted to the specialist who can read Chinese or the occasional visitor. Archaeological journals containing this information and published in China are entirely in Chinese, which drastically reduces their readership in other parts of the world. Thus, this exhibition and the catalogue produced for it (written by William Watson and William Willets) serves in a small but efficient way to reduce this gap.

A total of thirty-eight sites are represented, the majority covering the period from the Palaeolithic to the end of the Han (2nd century A.D.). A few photographs of objects dating to the centuries after the Han period and until the Sung Dynasty (10th century A.D.) are also included. Although the Chinese make a sharp distinction between objects of art-historical interest and those belonging to scientific archaeology, this exhibition includes both categories under the general title.

Of the early period certainly the most interesting excavation was that of an entire Neolithic village, unearthed at Pan-Po, near Sian (see DISCOVERY, 1958, vol. 19, p. 292). This site belongs to the painted pottery culture, or Yang-Shao culture, of which many sites in the Yellow River area have already been excavated. Remains of the Shang-Yin period were discovered near Cheng Chou. These included specimens of the famous oracle bones and bronze vessels used for ritual purposes. The opening of graves in the An-Yang area, already well known for Shang-Yin remains, have revealed that apart from the usual funerary objects, waggons and horses were also buried together with the human corpse.

FIG. 2. (*Right*) Earth casts of chariot burial. The most spectacular of these sites and one demanding very careful excavation was that at Ku-wei-Ts'un in the province of Honan, excavated in 1950. The burial of nineteen chariots arranged in two rows, dating back to the late Chou period (4th–3rd century B.C.) was revealed. The wooden frames had rotted away, leaving in their place earth casts of firm soil. The excavation of this site was similar to that of the ship burial at Sutton Hoo.

(Photographs by courtesy of Britain-China Friendship Association)

FIG. 1. (*Left*) Grave with skeleton and pottery. A Neolithic grave from a site near Lanchow in Kansu province. The corpse is buried together with painted pottery belonging to the Pan-Shan and Yang-Shao cultures. This site was excavated in 1954.

Remains of the Chou period include bronze ritual vessels of great beauty. At some sites iron tools were also found, suggesting thereby an early use of iron. Objects dating to the Han period occur mainly in the large and elaborate tombs built for the noblemen. The exhibition includes photographs of some murals depicting local life found in a tomb at Wang-Tu. This is in addition to stone slabs with vivid low reliefs from other tombs. Pottery models of homes, farms, boats, and so forth, are also to be found at such sites. Han dynasty tombs are now being found in increasing quantities. Whereas previously such a find was considered a rare event, it is now regarded as one of the many, since in the Lo-Yang area alone more than 200 Han tombs had been excavated by 1954, supplying about 10,000 objects of great interest. The Han period is thus rapidly becoming one of the most fully documented periods of Chinese history.

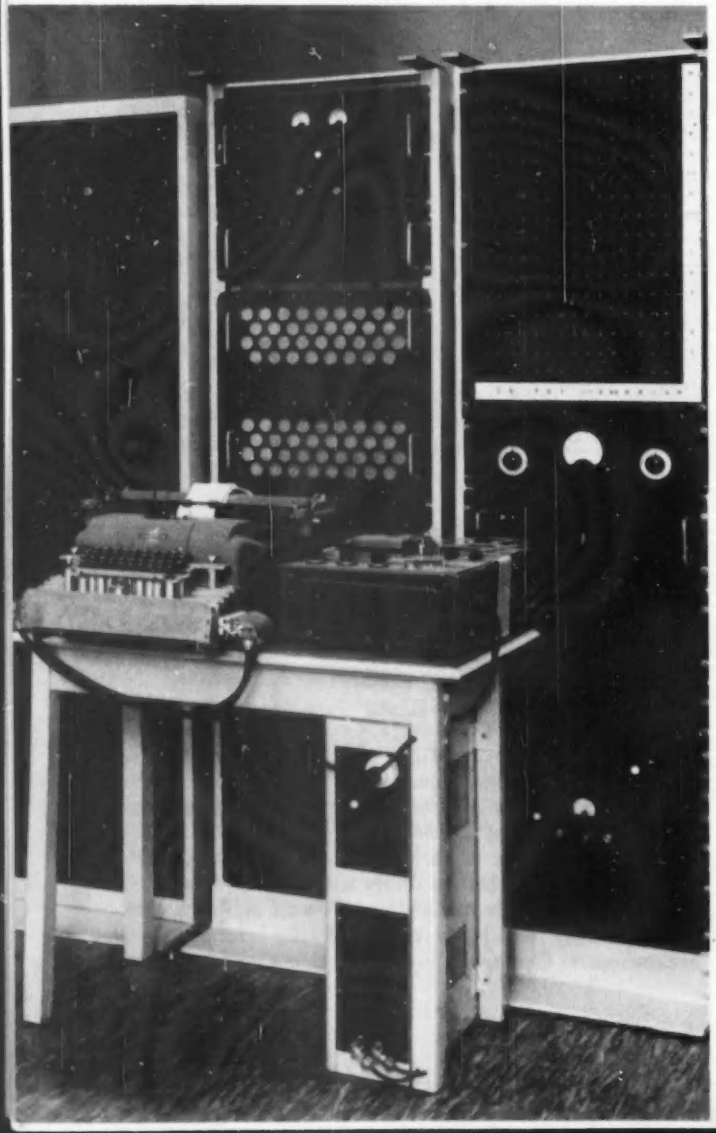
Finds from other sites dated to later periods tend to be of art-historical interest. These include specimens of Buddhist sculpture, tomb reliefs and murals, tomb figures, and porcelain of various kinds.

The most overwhelming impression at the exhibition is that of the abundance and range of the finds. Certain areas such as the basin of the Yellow River are particularly rich. Thus the objects are unearthed both during planned excavations, and in the course of digging for other purposes, as for instance the laying of a railway line, or the building of a factory ("construction work", as it is called). The photographs showed objects obtained by both means.

This richness in material necessitates a more than ordinary interest in archaeological research by the educational and civil authorities in each area. The amount of archaeological work that is accomplished is indeed remarkable, considering the lack of trained archaeologists. This fact was emphasised by Mr Huan Hsiang, the Chargé d'Affaires for China, when he opened the exhibition. He expressed the hope that the future would see a more active exchange between Chinese and non-Chinese archaeologists, when possibly the latter could actually participate in excavations in China.

FIG. 1. Optimal coding device shown at the Mechanisation of Thought Processes Conference.

FIG. 2. Automatic speech recognition device.



What is the Difference Between a Brain and a Computer?

A decade ago, when the big electronic machines were going into service in the solution of problems in research and industry, computers were commonly referred to as "brains". But experience has made clear the need of caution in the use of this term. The outstanding virtue of a computer is that it can carry out the simple operations of arithmetic much more quickly than human beings, so that it can produce the results of mathematical calculations with superhuman speed and can tackle others whose sheer complexity (or tedium) put them beyond the range of human effort. But this skill, people say, does not constitute "thinking". It is still necessary for human beings to prepare very detailed lists of instructions before a machine can be set to work on a mathematical operation, and it is still necessary that these human programmers should anticipate even the trivial difficulties which their computer is likely to stumble across. For these reasons we have come to think of computers not as brains but as useful aids to those of the human variety.

This comforting notion was more than a little disturbed by the conference on the "Mechanisation of Thought Processes" held in November 1958 at the National Physical Laboratory. It was attended by 200 specialists from a score of countries, including Hungary and the Soviet Union as well as the United States. Their purpose was to explore the ways in which it may be possible to endow computing machinery of one kind or another with some of the more creative attributes of human thought—an ability to learn from experience, to exercise judgment, to invent new ways of tackling insoluble problems, to solve problems which human beings have not thought of and, in general, to carry out those processes of inductive logic—those creative leaps into the dark—of which human beings are so proud. The proceedings of the conference made it plain that work on these tasks is only just beginning—there are many more ideas than actual working machines. On the other hand hopes of success are running high, and it is not unreasonable to expect that the conference will turn out to have marked the beginning of a new science—an amalgam of computer engineering, mathematical logic, animal psychology, and anatomical neurology.

The lines of development which are already apparent have in fact been fertilised by concepts belonging to each of these disciplines. So far most progress appears to have been made in a few attempts to make machines which will learn from experience.

Two essays of this kind were described at the conference. From Teddington itself Dr A. M. Uttley and Dr A. M. Andrew described the principle and the possible applications of devices which are called "conditional probability" computers. The basic idea is that the machine can be built so as to learn which kinds of response are appropriate to particular stimuli in much the same way as a human being can learn to find his way out of a maze. Briefly, the machines work (or will work when they are built in larger numbers) by keeping a record of which responses have been appropriate, and which inappropriate, during some educational period to which they have been

exposed, and using this information to form a notion of which kinds of response are most likely to be successful when repetitions of the circumstances during which it has been "educated" may occur. Work at the National Physical Laboratory has now been started on the design of a machine which will, in this way, be able to learn how to control chemical processes which are themselves too complicated to be subjected to numerical analysis.

A similar machine with a very different purpose was described by Dr O. G. Selfridge of MIT. This is called "Pandemonium", and Dr Selfridge considers its most general form to be an illuminating analogy with human thinking processes. The version which has already been built is being used in the automatic decoding of manually keyed Morse code. This is a difficult problem (for machines—not humans) because the lengths of dots and dashes vary considerably from one Morse operator to another and from the beginning to the end of a single message. Pandemonium "learns" to decipher passages of Morse by deciding which of more than a hundred of the electronic units of which it is built provide accurate estimates of meaning of smaller pieces of the code and which are so unreliable that their indications may be ignored.

But learning from experience is not all of human creative thought. Another aspect of it which is being given close attention is the human ability to distinguish from a mass of complex information features which may be significant.

In the field of computers practical needs have inspired an excursion into the mechanised thought. For a long time it has been recognised that the process of preparing lists of instructions for electronic computers to carry out is a tedious and expensive use of human intelligence. Therefore in the U.K. and the United States successful attempts have been made to transfer a great deal of this tedium to the machines themselves. In practice this implies that the computers must be provided with a mathematical background sufficient for them to decide how mathematical problems should be solved, and how to organise the arithmetical work entailed. The result has been that several computers are now equipped to accept mathematical problems specified in some simple algebraic form and to handle the solution of these without further intervention. At the National Physical Laboratory it was clear that the men in charge of the machines hope that they will be able to go much further than this—to the point at which machines will decide for themselves which of several alternative methods is best for solving particular problems and to the application of known methods of solution to problems which have not yet been solved by humans. Though nobody can say whether it will be attained, the long-term objective in this work is a computer that will be able to think up new methods of solution and even new problems.

If and when this becomes possible it is widely thought that the processes which go on inside the thinking machines will be too complex for human beings to follow. This prospect is plainly one that will alarm those who fear that Orwell's *1984* is just round the corner. Accordingly it may be comforting to acknowledge that the conference at Teddington was a remarkable stimulant to human intellectual activity and not a threat to its independence and integrity.

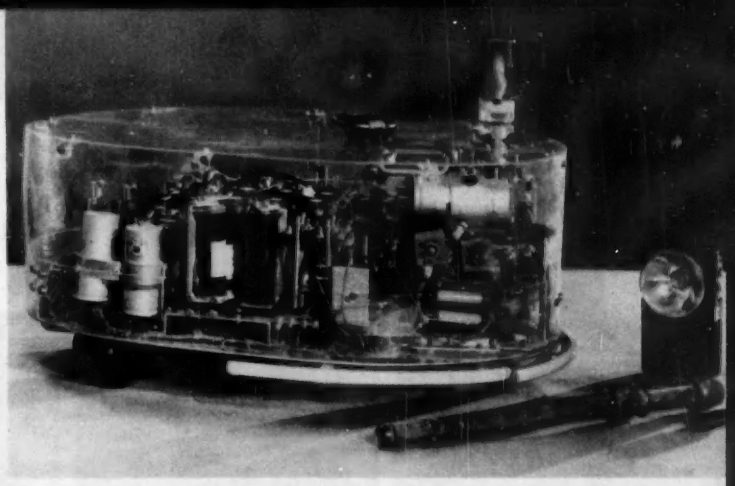
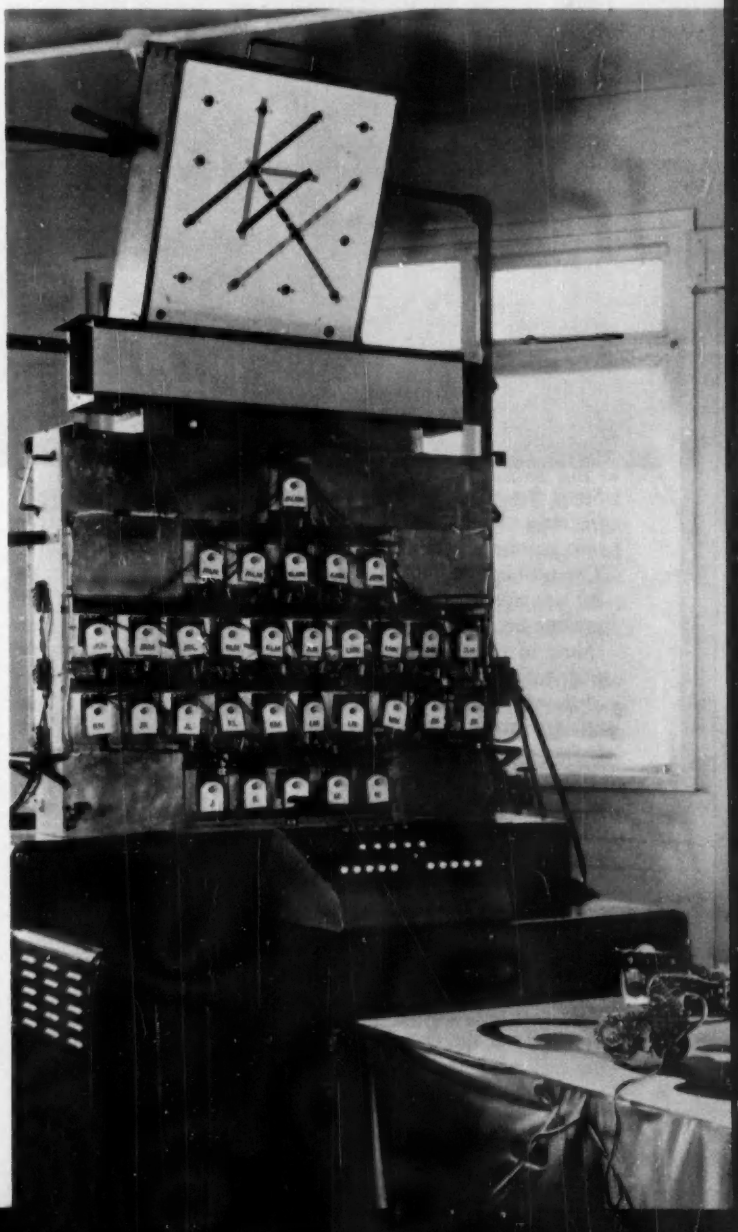


FIG. 3. *Machina Reproducatrix.*

FIG. 4. Conditional probability computer.



THE FAIREY-FERRANTI 3-D MILLER

R. COLEMAN, J. GREGSON AND A. FLETT

Production Engineer — *Production Development Engineer* — *Project Engineer (Machine Tool Design)*

Fairey Aviation Company, Stockport, England

FIG. 1. The cutter of the machine is surrounded by a fixed brush which directs ships into the conveyor below the table. It is expected that future cutting-head developments will necessitate the removal of up to 600 cu. in. of metal per minute in the form of swarf.

Since the advent of the gas-turbine the tendency towards higher and higher speeds for aircraft has led to a considerable amount of rethinking in the design of aircraft structure. The problem simply stated, is a demand for more strength in less space and at less weight, combined with much greater accuracy of manufacture, in both the aerodynamic shape of the aircraft and in the internal structures where wide tolerances incur severe weight penalties. The main line of development has been towards integral construction; the change from multi-component structures with riveted or bolted assemblies to single-piece major components.

The original concept, particularly in the U.S.A., was for manufacture of these components from light-alloy forgings of unprecedented size, and in America, a programme for the installation of heavy forging presses was prepared. The long-term nature of the manufacture of these very large presses created interest in the possibility of the manufacture of relatively small components from solid slab material, primarily as an interim measure, and secondly to deal with prototype work.

The experience gained in the U.S.A. from the performance of the first presses installed soon brought to light the following severe limitations of the forging conception of integral construction: large forging dies are extremely costly and take a long time to manufacture; the introduction of even a minor modification becomes a serious matter, both in time and money; the close tolerances required could not be achieved by forging, and more and more machining became necessary after the forging operation; and the distortion caused by stresses released during machining could not be rectified.

The many difficulties encountered caused the U.S.A. to review their policy and the result was a drastic pruning of the heavy-press programme and an increasing emphasis on machining from slab material. In the United Kingdom the enormous capital outlay necessary for heavy presses was not available and the slab-machining technique was recognised as the only possible line of development for the British aircraft manufacturer. This resulted in parallel action on both sides of the Atlantic, but before any real development work could be initiated on shaping components, there were still two outstanding problems to be overcome in connexion with the slab material itself. These were the distortion arising from stresses released during machining, and the reduction in transverse elongation properties as slab thickness is increased.

RESEARCH AND DEVELOPMENT

The first problem was resolved by carrying out a stretching operation on the slab in the direction of the grain. This process is not applicable to forgings, since a constant cross-sectional area is necessary in order to secure even stress stabilisation throughout the material. Large stretching machines of several thousand tons capacity, capable of dealing with the maximum size of slab required, have now been installed both here and in the U.S.A.

The transverse elongation of the slab is a function of the amount and type of working the material receives in the process of manufacture, and satisfactory values have now been achieved for even the thickest slabs by carefully controlled pre-forging operations prior to rolling.

Encouraged by the material developments, the Fairey Aviation Company initiated a research and development programme on the manufacture of slab components. The over-riding factor in any manufacturing process is the economic one and, in the case of machining integral components from slab, the governing factor is the enormous quantity of material which must be removed from the slab to produce the finished component, this being in the order of 90% of the initial slab weight. It naturally follows that an investigation into the machining of light alloys was the first step.

Test equipment was assembled to study the effects of cutting at high speeds of up to 12,000 surface ft./min. An interesting feature revealed in metal cutting at these very high speeds, is that the heat generated in the process is contained in the cuttings produced and is not transferred to either the cutter or the slab material. This is most important, since cooling a high-speed milling cutter is extremely difficult, and of course, heating of the slab would cause severe distortion. Metal pick-up and welding to the cutter was the major problem encountered, but this was resolved by injecting oil-mist directly on to the cutting face, from jets embodied in the cutter. With this technique a very high standard of surface finish was achieved.

It soon became evident that existing practice was not nearly approaching the full exploitation possibilities of light-alloy machining and work proceeded with the development of a series of self-contained high-speed spindles of up to 20 h.p. and 6000 r.p.m. Provided with suitable traverse movements, these could become economic cutting engines capable of exceeding, by very high factors, the efficiencies of conventional machine tools, which generally are designed primarily for steel cutting, with minor variations to embrace the light alloys.

The next stage in the programme was an investigation of the machine-tool problems, in order to achieve optimum utilisation. It was obvious from the results of the cutting test that hand-controlled machines were not capable of utilising the full cutting potential and, since structural components must naturally be of diverse shape, a more sophisticated method of power control was essential.

AUTOMATIC CONTROL

A comprehensive survey was made of controlled machines in operation or under development both in Europe and in the U.S.A. In the meantime, a production component was selected and redesigned as a slab component, in order that comparative information could be obtained from its manufacture. In parallel with this, a machine was converted for template copying using hydraulic control, in order, primarily, to gain actual experience of the control problem.

This machine, known affectionately as the "Green Linnet", has been producing components for the Fairey Gannet anti-submarine aircraft for a number of years.

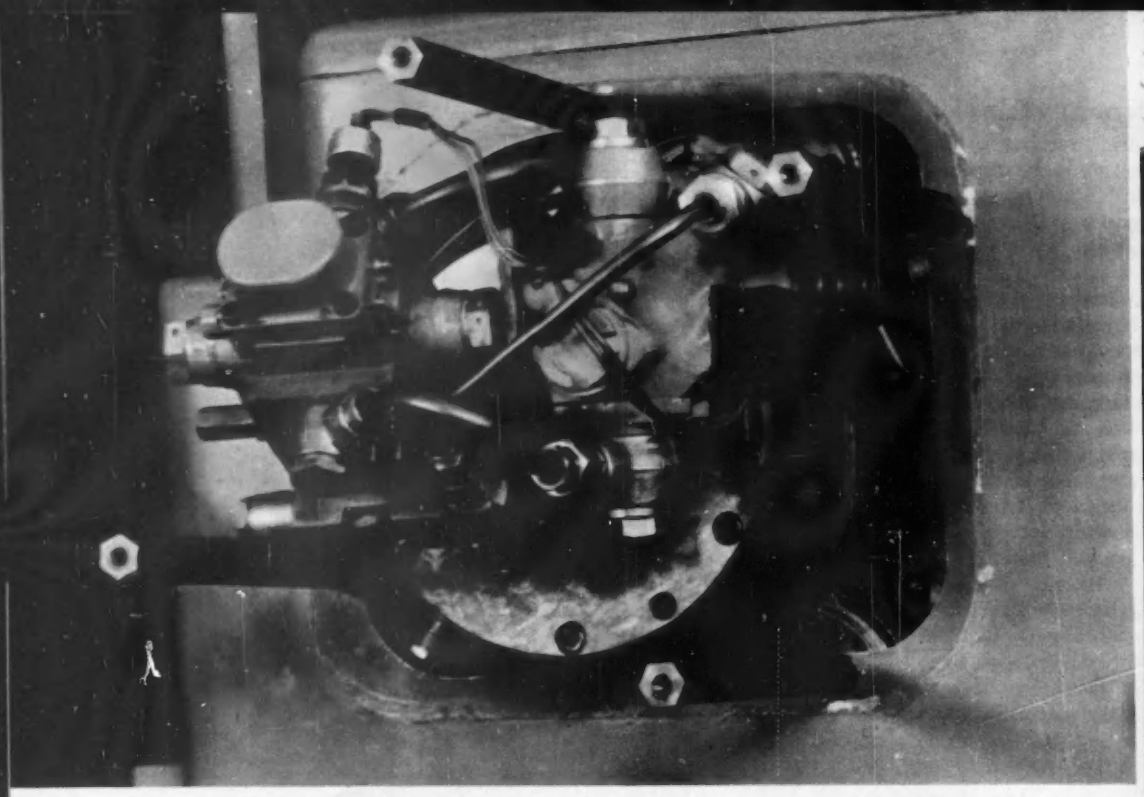
A large variety of template copying systems was available at this stage, mainly from the U.S.A. and the European mainland countries. The Massachusetts Institute of Technology in the U.S.A. were also operating a numerical control system which embodied some computer elements. The tracer systems were offered as basically accurate systems, where high accuracies could be achieved providing the machine to which they were applied was capable of utilising the control information. The requirements of such a machine were that it should possess: a slide system having the lowest possible coefficients of static and dynamic friction and free from sudden fluctuations in friction ("stick-slip") at all speeds; a drive system of extremely high stiffness, combined with low inertia and free from backlash under all drive conditions; structural members of high mechanical stiffness with minimum mass; and an efficient cutting spindle with a high degree of rigidity.

Deficiency in any of these features will bring about a resultant loss of accuracy, the first three items being the primary requirements of any piece of mechanical equipment controlled by a closed-loop servo system. Such a machine tool was not in existence and virtually nothing was as yet being made available by the machine-tool industry of this country to meet the demands of the aircraft industry for such a machine.

REDUCING FRICTION

Ball- and roller-bearing slides were already a feature of some smaller machines and attempts were made to adapt these and pads of low-friction plastic materials, to meet the friction problems of the larger machine tools, notably in the U.S.A. On the drive-system problem considerable efforts were made by the oil companies to produce oils of low compressibility to overcome the fundamental lack of stiffness of ram systems, while the gearing approach was generally to utilise more accurately cut gears with reduced running clearance to minimise backlash. The structural problem was being met to a large extent by replacing cast iron with carefully designed light-weight welded steel structures of comparable rigidity.

It was felt that these efforts fell far short of meeting the requirements and that machine-tool design still lagged a long way behind the development of control methods. Theoretical calculations on drive systems indicated that, where relatively large masses are to be moved, a system using gear-driven pinions operating on a rack was capable of a higher efficiency and stiffness to inertia ratio than screw systems or hydraulic rams, although the recirculating ball nut and screw (in which balls are interposed between the threads of nut and screw and are allowed to return from one end of the nut to the other through a suitable passage) is suitable where the load is small and the drive length relatively short. A design study was undertaken of a rack and pinion drive gearbox with two parallel gear trains loaded against each other, incorporating a pre-loading



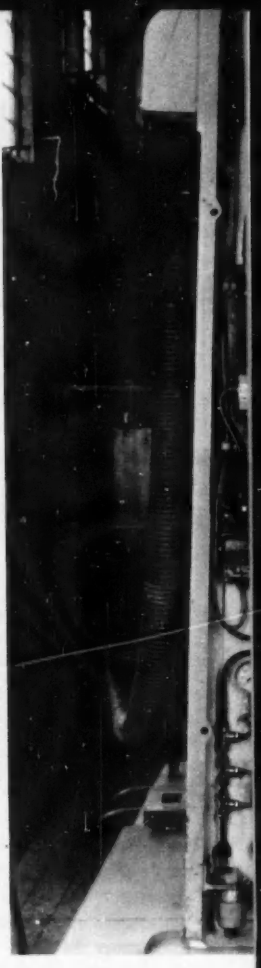


FIG. 2. (*Left*) The hydraulic motor and servo valve assembly for controlling the vertical traverse of the cutting head.

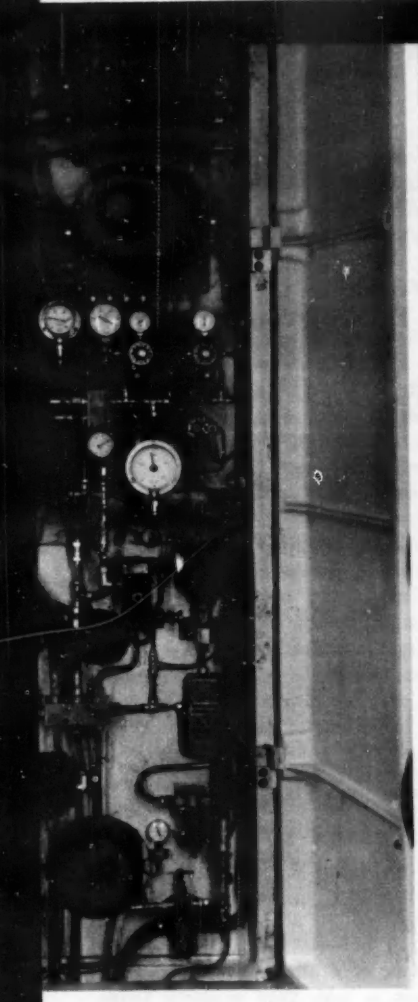
FIG. 3. (*Centre*) A compartment in the rear of the column houses the hydraulic, pneumatic, and electrical equipment.

device to eliminate backlash independent of gear tooth clearance. Gearboxes of this type have since been built and, under extreme test conditions, have fully met the performance requirements.

Much experimental work was done on slide-friction problems where it was found that a form of pressurised oil system affording some measure of load relief would be superior to the low-friction material pads and capable of carrying higher loads than the ball or roller system, where irregular surface deformation under load is the major fault. A suitable machine geometry was established to meet the production requirements and the estimated slide loads were plotted for a group of suitably spaced support points. These included all the dynamic and cutter load combinations as well as the static loads, the object being to provide a series of support pockets into which oil would be forced at a pressure slightly lower than that required to balance the minimum load occurring at that point so that the slide friction would be a function of the residual load only and, in addition, slide contact would be maintained under all conditions. During the investigation into the method of controlling the large assortment of pressures required, it was realised that if the oil was allowed to flow continually from the pockets, causing the slide faces to separate, and if the flow was in some way limited, then the small variations in the slide gap could serve to control the pocket pressures and thus form a simple closed-loop servo system. The initial calculations based on a simple form of control showed that a slide system was possible where the sliding members would be completely separated by a control film of oil and yet have a stiffness comparable to that of the structural members when subjected to a varying load. Further test work was then carried out on an experimental rig embodying this system and the results obtained formed a basis for the design of the slides of the machine. The phenomenally low frictional results recorded on a full-scale test bed are quoted later in this article.

ELECTRONIC CONTROL IN 3-D

While the experimental work and design studies were in progress, research was being made in this country and in the U.S.A. into the electronic control of machine tools direct from programmed dimensional data. A programme control system, that is to say one in which the machine operations are controlled by a predetermined programme of dimensional and other instructions supplied to the machine in tape form, offers obvious advantages over a template-following system. Apart from the fact that no templates need be manufactured, the programme system is capable of issuing advance information to the machine, the main feature being control of acceleration demands. In the case of a heavy machine tool operating at high speeds following a template, when the tracer reaches a corner or sharp change of shape on the template, the machine receives a demand possibly to stop travelling in the X direction and start moving along Y. This constitutes an infinite acceleration demand which cannot be met and the machine overshoots. This means that the tracer's speed must be reduced for the whole of that operation to the point where the amount of overshoot occurring is within the permissible limits. Under electronic programme control the acceleration demand can be automatically limited so that the machine can operate at full speed throughout the machin-



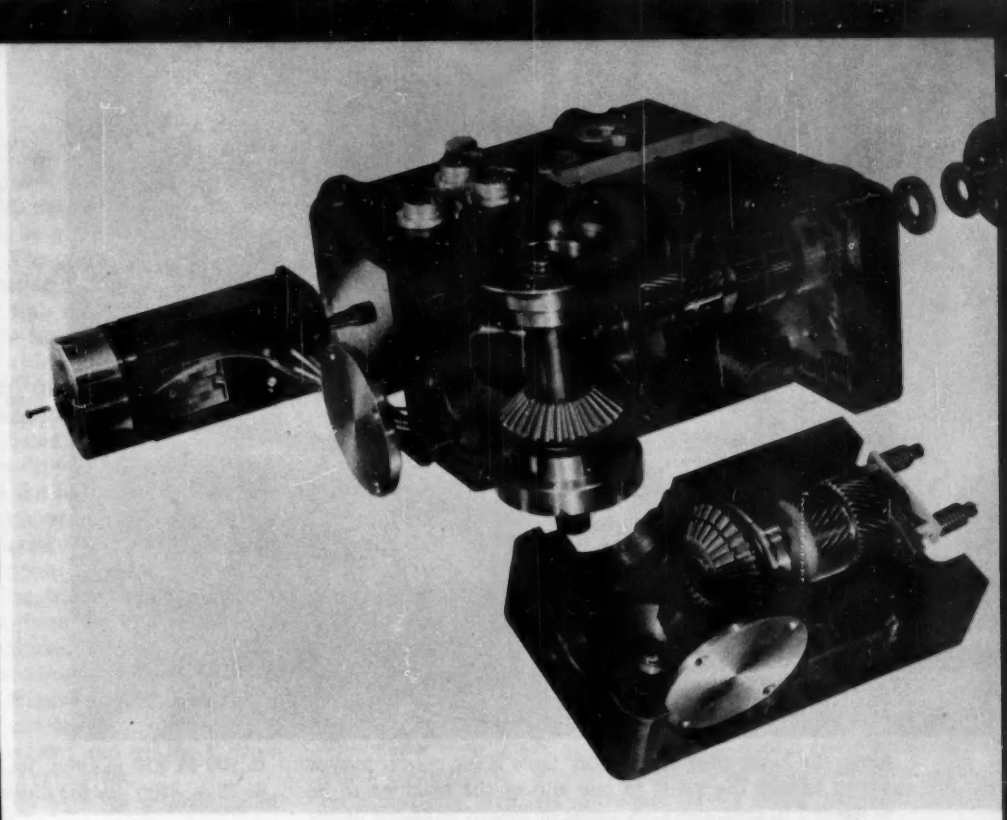


FIG. 4. (*Right*) An exploded view of the standard Ferranti gearbox.

ing operation, decelerating only where a change of shape demands it. In this way the high machining speeds available are utilised economically.

Various programme control systems were investigated, the most advanced of these being the Ferranti digital system in which a computer is used to process the planning information, the machine control equipment being simply a servo system utilising as its input the magnetic-tape recording produced by the computer. The method of measurement adopted was the use of optical diffraction gratings which are completely independent of the drive system and measure movement of the slides directly, thereby embracing the complete machine within the control loop (DISCOVERY, 1957, vol. 18, p. 370). The more common approach was to control the machine up to the gearbox input side or the driven end of the lead screw and disregard inaccuracies occurring beyond that point.

Another outstanding feature of the Ferranti system was the simplicity of the programme information required. This is kept to a basic minimum, the computer handling all the necessary calculations in contrast to the other systems, which entail the laborious plotting of intermediate points, the spacing of which gives an approximate shape related to the accuracy required. It was quite clear at this stage that existing machines which were available, either with tracer or programme control systems, were inadequate to cope economically with aircraft requirements. In some instances speed was available, in others accuracy, both the two fundamental requirements never occurred together on one machine.

Knowing the requirements of the aircraft industry, and having a sound background of mechanical development, Fairey's prepared a scheme for a machine tool capable of utilising the full control possibilities of the Ferranti system. The machine would have a high degree of accuracy and be at the same time, an efficient cutting engine, thus making integral construction an economic proposition. This had been made possible through a proposal put before and supported by the Aircraft Production Development Directorate of the Ministry of Supply. A development contract was issued in late 1955 for the design and manufacture of the machine, and included for full-scale testing of the various unorthodox features to be progressively conducted throughout the construction programme and continued until the machine was completed, when it would be subjected to a comprehensive series of performance tests.

THE MACHINE

The machine weighs 50 tons and has a vertical column travelling a distance of 25 ft. along the bed, this forming the X axis of the machine. Mounted on the face of the column is the head carriage travelling vertically along the Y axis with a movement of 7 ft.

The cutting head is fixed to a cross-slide on the head carriage and has an infeed movement of 12 in. along the Z axis. These X, Y, and Z movements are servo controlled from the pulse information recorded on the magnetic tape.

The cutter serves the vertical work table which is 8 ft. high and 28 ft. long and is formed of four cast-iron slabs 15 in. deep mounted on three buttress supports. These stand on base castings fastened to the machine bed and allow the table to be set at a suitable distance from the cutting head, with a range of adjustment of 24 in. Running

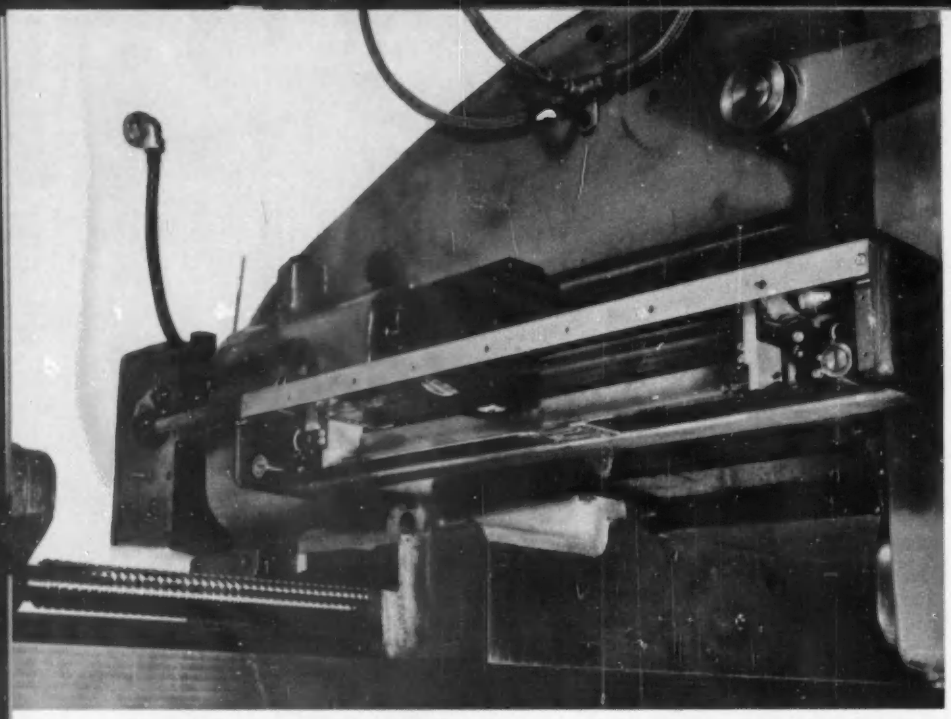


FIG. 5. A view of the Ferranti grating measuring system applied to the cross slide of a small vertical milling machine.

along the lower edge of the work table is the chip conveyor which carries the swarf to one end of the machine to be deposited in containers. A series of hinged deflector plates on the conveyor can be closed to form a walkway along the full length of the table to facilitate component handling. Slide faces and other functional parts of the machine are fully protected by flexible covers against the ingress of swarf.

Hydraulic and electrical power supplies are enclosed in a separate housing away from the machine. The operator normally stands in front of the Ferranti control desk and behind him is the contactor panel containing the heavy electrical switchgear. On the platform at the base of the column is the hand control box mounted on a hinged pedestal which can be used for manual operation of the machine and setting up to component data, two manual speeds being provided on each of the three movements, a normal operating speed for cutting and a pick-off speed at which single movements of 0·001 in. can easily be selected. The electrical cables and air supply lines are brought into the column on an overhead boom hinged from a wall stanchion and the hydraulic oil supply passed through flexible pipes encased in armour sheathing rolling in a metal trough built along the front edge of the bed.

The weight of the head carriage is balanced by means of a hydraulic cylinder inside the column. Two roller chains transmit the load, over pulleys on top of the column and through a double sheave on the end of the piston, the outer ends being anchored to the top of the column. This gives a two-to-one ratio, enabling a cylinder of short stroke to be used. Oil at a pressure of 1000 lb./sq. in. is supplied to the upper end of the cylinder from a reducing valve in the hydraulic supply line. On the upward stroke of the piston as the carriage moves down, the oil is exhausted to the return line through a spring-loaded relief valve. The traverse speeds on the machine are infinitely variable up to the maximum of 150 in./min. on X and Y, and 75 in./min. on Z. The normal operating range used in production is 100 to 150 in./min. for the roughing operations and 50 to 75 in./min. for the finishing operations.

LUBRICATION AND DRIVE SYSTEM

The method of slide lubrication used is a unique version of the hydrostatic pressure system in which the moving members are entirely supported on an oil film with no direct metal-to-metal contact between the bearing faces. An automatic metering device controls the pressure of the separating oil film in such a way that external loads applied to moving members cause an opposing force system to be set up in the oil film to balance the loads and maintain the rigid location of the slide. The system thus accommodates all the cutting and inertial loads encountered and the frictional forces are entirely viscous and independent of the loads on the slide. The main bed-slide of the machine under test with a 9-ton load gave the following "friction force" to "speed" relationship: at 10 in./min., force required=2 lb.; at 100 in./min., force required=20 lb.; at 200 in./min., force required=40 lb.

A reduction of the load from 9 tons to 1 ton caused a slide movement of only 0·0003 in. from the mean setting, the carriage still floating freely. This system is virtually free from wear, there being no metal-to-metal contact and so the accuracy and efficiency of the slides will be maintained indefinitely.

It is quite common in a conventional machine tool drive system to find that the drive motor can be turned through a considerable number of revolutions before the machine begins to move, due to backlash between the mating teeth of the gearing and wind-up or elasticity in the gear shafts and bearings. If a controlled machine tool is to follow the control information with any degree of accuracy, then these conditions must be eliminated. The drive power for the Fairey machine is by high-speed hydraulic motors of extremely low inertia coupled to specially designed gearboxes. The Ferranti standard ½-h.p. type gearbox is used on the infeed movement

driving on to a recirculating ball lead screw engaging with a double-nut system with spring pre-load. The larger gearboxes on the *X* and *Y* movements are of Fairey design and are twin-train boxes terminating in a pair of spur pinions driving on to a common rack. The gear loop is closed at the input end by an axially floating shaft with right- and left-hand helical pins engaging with the first gear in each of the two trains. Pneumatically loaded bellows apply an axial load to the floating shaft which results in a pre-load torque being applied throughout the two trains, equal to 110% of full load torque. Under conditions of no load the pre-load torque is equally distributed through the two gear trains and it is taken up by the driving train as the drive torque is applied. At full load the remaining 10% of the pre-load exerted on the non-driving train maintains the backlash-free condition. The axial float of the pre-load shaft accommodates any tooth ripple or eccentricity errors in the gearing and, over a period, automatically takes up tooth wear. The gears, shafts, bearings, and mountings were designed for optimum conditions of high stiffness with low inertia and it is due to these considerations, combined with virtual absence of slide friction, that the resonant frequency values recorded on test were: for the *X* drive with an 8½-ton column, 22 cycles/sec., and for the *Y* drive with the 1-ton vertical carriage, 63 cycles/sec.

These figures are exceptionally high for a machine of this size and indicate that the machine is able to respond with extreme rapidity to any demands made on it by the control system for high acceleration or deceleration due to changes of profile during machining—or, in other words, that at high feed rates the movements of the driving motors as determined by the control system are accurately reproduced by the cutter.

THE CUTTING HEAD

The cutting head is a Fairey-designed unit of 20 h.p. running at 6000 r.p.m. and has been tested on the machine up to metal-removal rates of 140 cu. in./min. for face milling, 110 cu. in./min. for end mills of 2 in. and 3 in. diameter. The surface finish obtained at these rates was around 10 micro in., which is equivalent to a fine ground finish.

Briefly, the sequence of operations in the Ferranti programme control system is as follows. The designer produces a drawing of the part to be machined, dimensioned with respect to a datum, each point being given three rectangular co-ordinates, representing distances in the *X*, *Y*, and *Z* planes from the common datum. Points to be dimensioned are those where the two curves intersect; for example, where a straight line joins a radius. From the drawing a planner prepares the machining programme specifying the route to be followed by the cutter and inserts information concerning cutter diameter and feed rate and also the shape of the path between the change points, a set of code symbols being used to denote a circle, an ellipse, a parabola, or any other second-degree curve, the absence of a shape symbol denoting a straight line.

The programme sheet is then copy-typed on a Creed teletypewriter which produces a typescript check copy and simultaneously a paper tape with a series of punched holes representing the programme information in binary code. This paper tape serves as an input to a digital computer which translates the information into a set of pulse-trains on a magnetic tape, the computer service being provided by Ferranti.

The three pulse channels on the tape control the *X*, *Y*, and *Z* movements of the machine, each pulse representing a distance of 0·001 in. and the pulse-train recorded on a fourth channel provides a continuous check on the three control channels. When the magnetic tape is played back on the machine control desk, the command pulses are passed through the control equipment which transmits corresponding signals to the machine servos, so that the machine follows the pattern of movements recorded on the tape to produce the shape initially programmed.

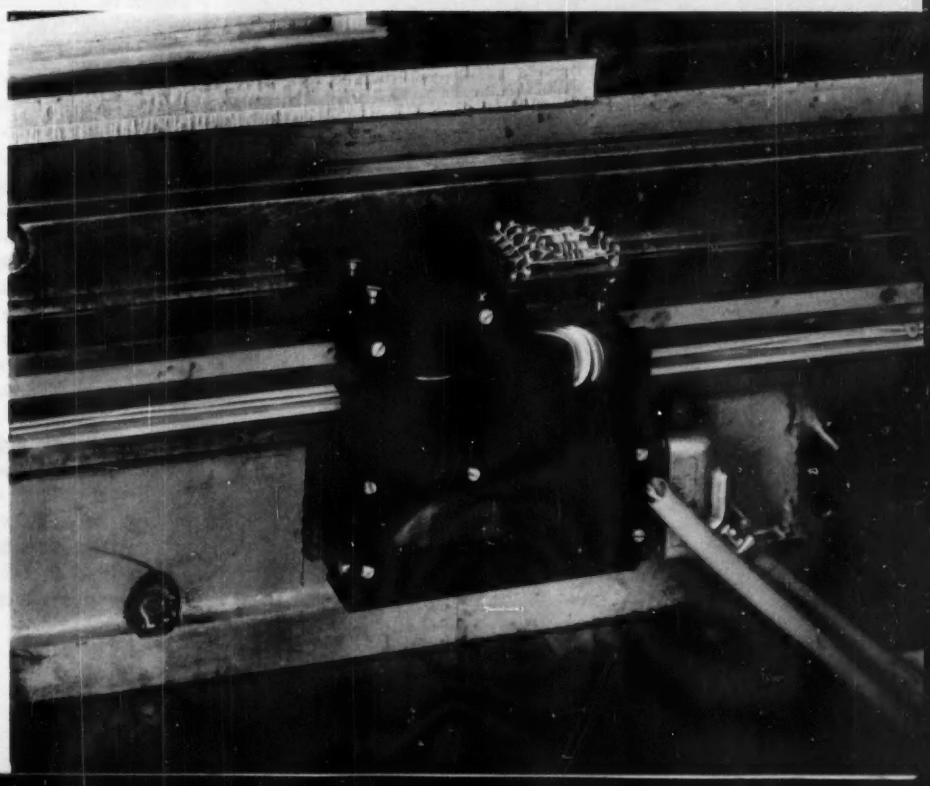


FIG. 6. Typical grating assembly together with the optical box in position.

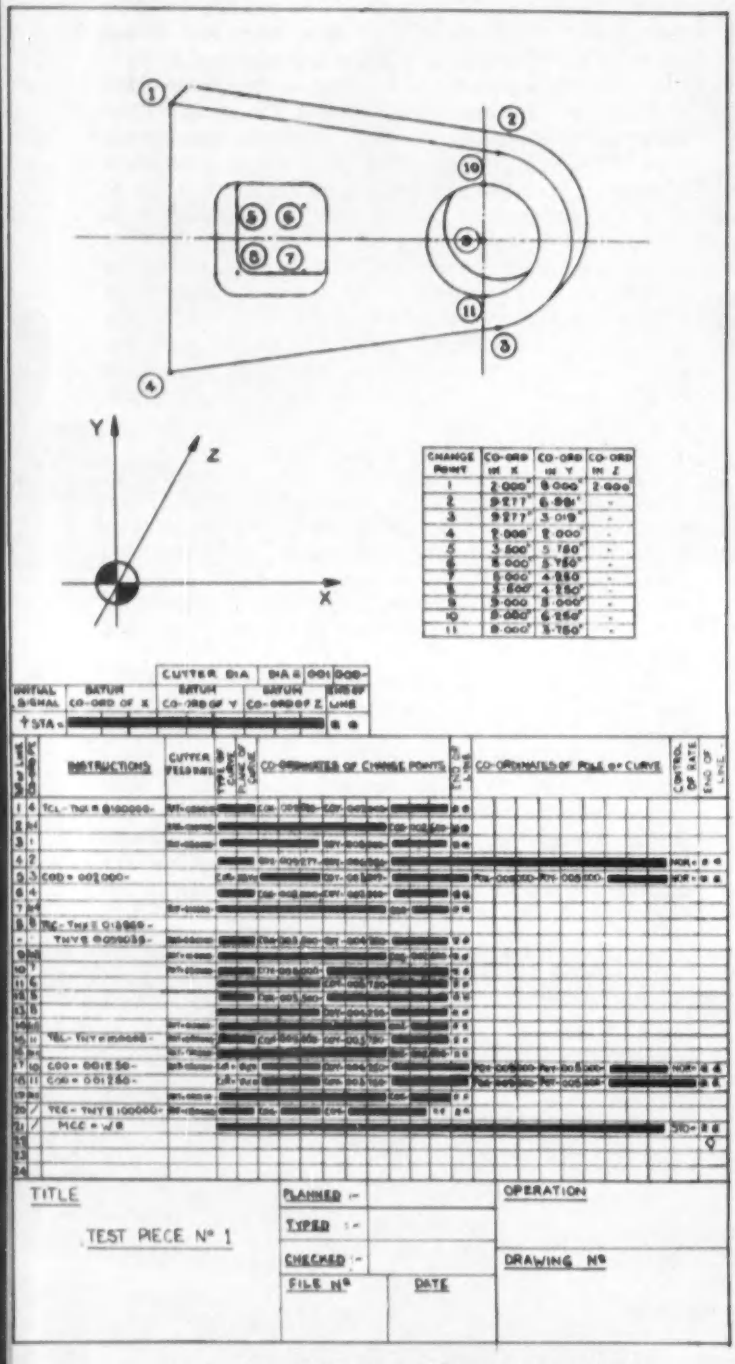


FIG. 7. Chart of *XYZ* co-ordinates and instructions to milling head movements.

Along the length of each axis of the machine is a glass grating, ruled over its full length with a pattern of fine dividing lines spaced with a frequency of 500 lines/in. These gratings are accurate reproductions of master gratings made by the National Physical Laboratory, Teddington. On the moving member a reading unit with a small section of similarly ruled grating placed at a slight angle to the long grating sets up a Moiré fringe pattern where alternate dark and light bands travel across the screen each time a line is passed. A group of photocells scan this fringe pattern and transmit two pulses for each line counted, so that each pulse, again, represents a distance of 0·001 in. In the control equipment the tape signals are amplified and after passing through a direction discriminator are held in a binary store.

CHECKING CIRCUITS

Feed-back signals from the optical grating on the machine pass through a similar direction discriminator and on to the binary store where the input and the output signals from the tape and grating are then compared and any discrepancy between the two is passed through a mixing network, amplified and passed on to the electro-hydraulic valve which controls the oil flow to the hydraulic motors on the drive gearboxes. The command pulses are also passed through a rate meter which gives a voltage output proportional to the velocity demand. In the mixing network this voltage is compared with the feed-back signal from a tacho generator in the gearbox and, here again, the difference in voltage is amplified and fed to the electro-hydraulic valve. This velocity loop provides the coarse position control for the machine, the resultant velocity being maintained within 5% of the command velocity. The displacement loop signal is superimposed on the velocity loop signal and gives the fine position control of the machine within 0·001 in. Considerable emphasis has been placed on electronic reliability and the circuits are designed to continue functioning correctly even if the value of any of the components varies by as much as 30%. As an additional precaution a daily check drill is instituted where the screen voltages of all the valves in each channel are reduced in turn, so that any component approaching the marginal condition can be replaced before the day's work commences. This marginal check occupies only 10 to 15 min. Checking circuits are provided to ensure that the errors in the machine movements never exceed a pre-set level. The check channel pulses from the tape are compared with the sum of the feed-back pulses from *X*, *Y*, and *Z* gratings and if the discrepancy between these exceeds 8 digits the machine stops. In addition to this, safety interlocks are also provided to stop the machine in case of failure of any of the services. Several refinements have been added to the control equipment supplied for this machine. The code symbol MCC-F appearing on a programme will automatically switch the control circuits to double pulse scale where traverse speeds of over 75 in./min. are being used, and at the end of each programme the symbol MCC-W is used to stop the tape-deck. A mirror image switch has also been added to the control desk so that right- and left-hand components can be produced from the same magnetic tape.

PERFORMANCE AND FUTURE DEVELOPMENTS

A comprehensive acceptance programme was devised by the Ministry of Supply to test every aspect of the machine performance. A full alignment check was made and a series of test pieces machined and inspected for accuracy and finish. Time trials were conducted under full cutting load and complete functional checks made on all services. Extremely good surface finishes were obtained even under full-load conditions, 8–10 micro in. r.m.s. at 110 in./min., with a 3-in. diameter end mill on a full face cut at 0·34 in. depth is a typical example. Dimensional accuracies of ±0·002 in. were achieved on dimensions up to 18 in. with repeatability within 0·001 in. over four consecutive test pieces. An elliptical channel section frame 7 ft. high, which entailed the machining of four elliptical paths, was produced with every dimension within 0·005 in., the part being programmed directly from the curve equations. All the test pieces were machined at the normal traverse rates quoted above.

It is too early yet to quote actual times against conventional method times, as the few components machined have not been produced in sufficient quantity by hand methods to achieve a settled production time. The time-saving in relation to these is, of course, fantastically high, but records are being compiled and these indicate so far that our original estimates of production rates between ten and thirty times faster than normal will be borne out.

Development work under the Ministry Specification is still proceeding on various features of the machine. Specially designed bearings will soon be ready for test for a 100 h.p. spindle to operate at 12,000 r.p.m. which will raise the cutting capacity to 500 cu. in./min. or even higher. Various aspects of angular control are being studied, the farthest advanced of these being a spindle adaptor carrying a variable angle cutter which will mill the changing angles normally encountered around the periphery of wing ribs. This can be achieved without any additional control equipment by locking the infeed movement and switching the *Z* channel over to the angular control. Design studies are also under way for a smaller version of the machine, tailored to meet the problems of milling high-tensile steel components.

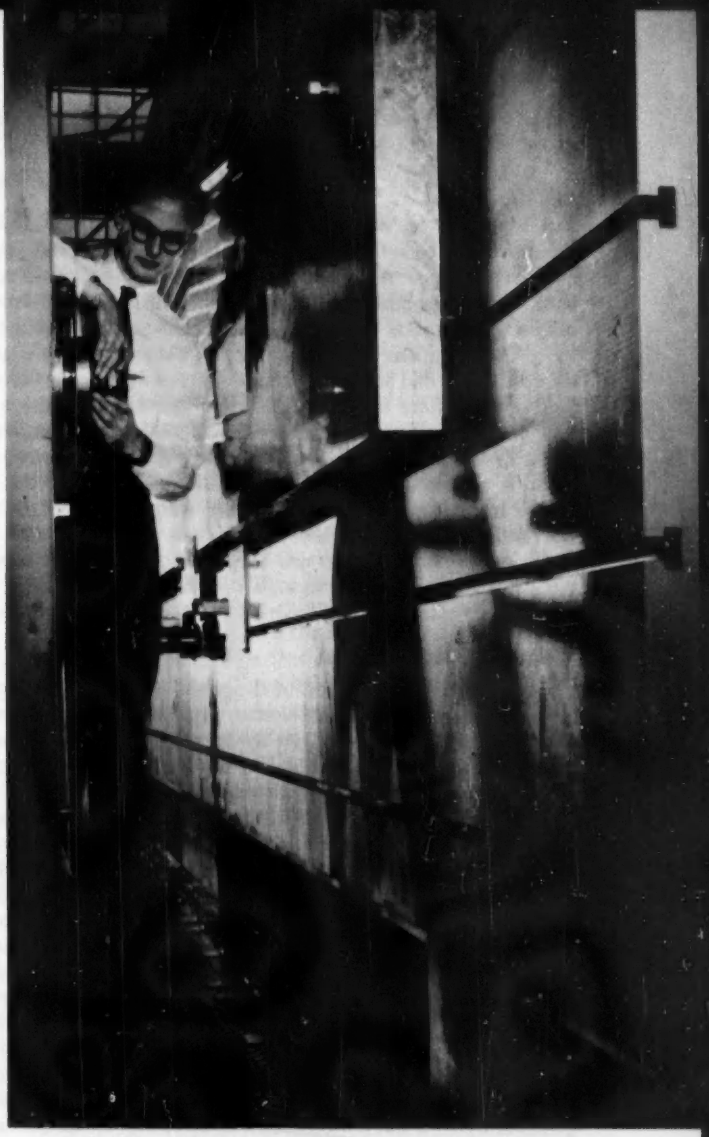


FIG. 8. (*Above*) The datum used for cutter setting can be seen mounted below the lower edge of the part-machined slab.

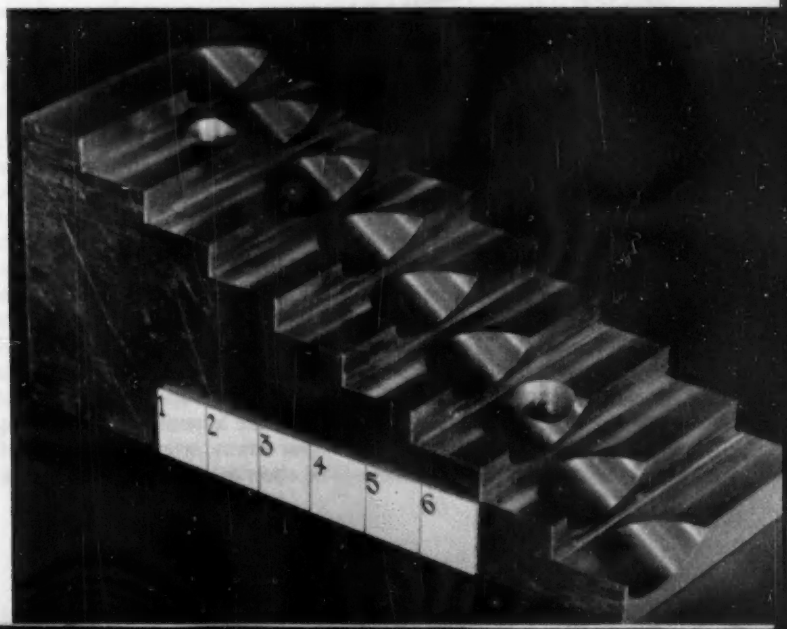


FIG. 9. (*Right*) One of the test pieces made as a check on the accuracy of work performed by the machine.

THINKING AND DISCOVERY

MAGNUS PYKE, Ph.D., B.Sc., F.R.I.C., F.R.S.E.

Not long ago an exhibition of mechanical gadgets considered to be of interest to Directors and Executives was held in London. Among the exhibits were an electronic truncheon for night-watchmen which could be used not only to hit burglars but to send out simultaneously a call to 999. The comment was made in one published report that the exhibition had something of the same atmosphere as one held a short time before in the same hall for schoolboys. The point I wish to make is that executives and schoolboys alike, in any age, accept as natural the intellectual environment in which they live. Today, cathode-ray tubes, electronic truncheons, or nuclear power-stations owing their operation to the principles of the Einstein equation $E=mc^2$ are commonplace and no one stops to think that the c of equation is the speed of light, a constant in which a Victorian businessman would have had no conceivable interest.

CHANGING IDEAS

We are living in a period of dramatic conceptual change in our outlook on the universe. Our understanding of physics was radically changed by Einstein in 1905 and the drive forward initiated then has not yet stopped. From Einstein and Planck we have already moved to Heisenberg's "uncertainty principle" and to the overthrow of parity by Yang and Lee. The technological advances based on the new conceptions have already given us aircraft moving faster than the speed of sound, *Sputniks* circling the earth and nuclear submarines navigating the Polar sea. There have been few intellectual revolutions as startling as the one in which we are living. The last period of such change in our insight was 300 years ago in the 17th century. Now, because men of our own generation have succeeded in making great new discoveries about the nature of the universe, a number of people have been trying to understand what it is that is needed to make a discovery. Is it, perhaps, possible to work out a mechanism of discovery so that, even if we cannot expect to make new discoveries to order, we may at least be able to put our minds into the best attitude to appreciate where a discovery may be expected?

Science, as we understand it today, is a way of thinking. There are four principles in science. The first group of three together make up one tenet. They are, that facts must be collected, if possible in quantitative terms, that a hypothesis should next be constructed to systematise the facts in relation to each other. This hypothesis may be sufficiently complete and radical to be termed a natural law. Newton's laws of motion are obvious examples. But whether or not a hypothesis is as important to science as the law of gravity or whether it is merely a working scheme to codify the various contiguous steps involved in alcoholic fermentation, it is only a scaffolding which must be modified or abandoned if subsequent facts show it to be inadequate. The third principle of scientific thinking is that experiments should be devised or peculiar circumstances sought to verify the hypothesis. If this new information conforms to the hypothesis, well and good. If not, the hypothesis, as I have said, must be changed. In other words, science takes no account of authority but only of observed fact. Finally, the fourth principle of science—its second tenet, if I may describe it as such—is that everything in the universe can eventually be fitted into an orderly natural law. This is admittedly an act of faith, but it is the faith which has been justified so dramatically in the last 300 years during which this kind of thinking has been applied to material affairs. It is by following this faith that we have achieved our great material successes—in industry, in medicine, and in agriculture, or, to put it more generally, in chemistry, biology, and physics.

THAT'S A FACT

But the matter is not as simple as it might seem at first glance. For example, what do we mean by "facts"? Few facts are unequivocal. The weight of a brass ball depends on whether it is measured in the laboratories of the Palestine Potash Company on the Dead Sea, or at the top of Mount Everest, or—to make things really difficult—in the pantry of a Comet IV travelling at 450 miles an hour over the Atlantic.

Prof. Norwood Hanson has just written a book, "Patterns of Discovery",[1] in which he cites a number of examples to show that a fact is not simply a definite "thing" about which there can be no argument, but that it is very much affected by the attitude of mind of the man observing it. Very few people are capable of swallowing a fact "neat", as it were. We almost all of us view the fact in the light of our current understanding of the universe. We look at a tree-trunk and see, half-way up, the four paws of a bear climbing the tree from the opposite side of the trunk from where we are standing. We only see its paws as it claws its way up. How do we know that the rest of it is bear and not, perhaps, an exceptional kind of pig with bears' feet? The answer is that, not being men from outer space, we have experience of our own world and know what sort of animal is the only beast which can be expected to be attached to that kind of paws. This is, even if only to a small degree, a speculative and subjective operation. After all, the first people in Europe to see a giraffe, did not believe it to be true! And in our own day, Einstein has demonstrated to us that a changed attitude of mind can lead to a very different picture of the universe from the one to which we are accustomed. Tycho Brahe, the great Danish astronomer of the 16th century, and his sometime assistant, Johannes Kepler, could both observe the identical fact, namely the sun rising above the eastern horizon. "Do they see the same thing?" Prof. Hanson asks, and this is a difficult question. Brahe might have said that he saw the sun swinging in its orbit round the earth, whereas to Kepler the phenomenon was the earth rolling towards the sun. It is no good our insisting that the observation for both was the retinal picture of a bright yellow object because, as Prof. Hanson rightly points out, seeing is an experience whereas a retinal reaction is only a physical state—a photochemical excitation. "People, not their eyes, see. Cameras and eyeballs, are blind," he writes.

In another respect there are special difficulties confronting the scientist who is trying to record facts, construct

hypotheses from them, and then verify the hypotheses by experiment, and that is that facts and experiments have to be recorded in words. And words too, like facts, change their meaning depending on the intellectual attitudes of the people who use them.

In collecting and measuring facts relating, say, to tissue regeneration, a biologist might have occasion to record observations on wounds. The word "wound" it might be thought describes a simple fact, a state of events. But this is not so. Let us grant that a wound implies damage to a living tissue more serious than a scratch. But a surgical operation, no matter how radical, is not a wound, nor is the incision made in the trunk of a rubber tree, nor the branding of cattle. The word "wound", therefore, carries with it all the implications of our understanding of what we mean by life and living—topics loaded with hypothesis and implication—as well as a series of assumptions about the cause of the phenomenon being observed. For example, is a ritual mutilation a wound?

An astronomer announcing the presence of "craters" on the moon is doing more than making a record of fact. "Crater" like "wound" is a word heavy with implications. A hole in the ground of a certain shape is not a crater. A crater implies a volcanic eruption or the fall of a meteor or an artillery shell. The word "poison" is not a simple description of fact. Inherent in it are, firstly, the understanding of normal life and function—two highly complex conceptions—and, secondly, the notion of a particular kind of chemical compound capable of harmful interference with life. Glass and steel are made up of chemical compounds yet ground glass and safety-pins, both of which are capable of harming living creatures, are hardly included in any normal definition of a poison.

The allegedly objective descriptions of scientific experiments are full of terms, ranging from the record of temperature and velocity and time all the way to more sophisticated measurements of acidity in terms of *p*H, of optical rotation, ultra-violet light absorption, or conductivity, or radioactivity, each of which, even the simplest, carries within it a whole series of assumptions based on experience and reported knowledge which all *may* be correct and relevant but which, on the other hand, may not. Prof. Hanson points out some of the complexities and assumptions in the word "stretch". To stretch something usually means to pull it out with the possibility, at least, that it will perhaps return part way to its former size. We stretch elastic bands, springs, muscles, and shrunk clothes. But does the wind stretch a cloud? Do we, in the technical sense, stretch a pat of butter? Perhaps the answer to this question is, yes. If so, it exemplifies in another way how a word can alter its meaning according to its context.

Theory-loaded words crowd around the scientist so closely that he comes to forget their devious character and, in the press of day-to-day affairs, may almost believe that they describe unequivocal facts. "Parallel", "insulator", "volatile", "excretion", "stress and strain", "nebula", "molecule"—all of these trail behind them a great panoply of assumption. It is within this framework that the scientific worker must collect facts as best he can and work out the hypotheses which his subsequent experiments will support or disprove. The interesting point then arises, by what intellectual mechanism does the scientist deduce the laws of nature, that is, these hypotheses by which he can reduce the confusing universe to an orderly system which he can command to his purpose?

SCIENTIFIC LAW-MAKING

There is a popular misconception that scientific laws emerge directly from the collection of facts; that a scientist has only got to amass sufficient observations for a natural law, or at least a working hypothesis, to emerge. A moment's reflection shows this not to be so in spite of Canon Raven's characterisation of a natural law as a "summary of statistical averages". An immense number of observations were available on combustion, nevertheless the fallacious "phlogiston theory" remained unchallenged for a very long time. The verification of a scientific hypothesis by experiment and observation is, perhaps, only a matter of hard work and reasonable competence. Once Pasteur had established the germ theory of disease, it was a matter primarily of honest scientific labour to identify a series of bacteria causing different diseases. The crucial question remains, however, as to how the hypothesis is to be invented in the first place. To do this requires ingenuity, tenacity, imagination, and conceptual boldness. Galileo struggled for thirty-four years before he was able to advance his hypothesis of constant acceleration. Mrs Beeton's advice to science is "first catch your hare". She made no suggestions to her readers on how this should be done (in fact, there is serious doubt as to whether she actually wrote this, her most famous sentence, at all). And in the same way, the correspondence schools on "how to be a successful author" usually begin by saying "having chosen a theme". The unsolved problem, however, is, what mixture of knowledge, intuition, and genius is required to conceive the theme or hypothesis which is subsequently to be verified.

Kepler's first hypothesis of the motion of Mars rested on the principle, fundamental to the astronomical tradition into which he was born, that the planet moved in a perfect circle. Only after long and gruelling thinking about the errors he found between theory and observation did he slowly come to suspect that perhaps his predecessors of the previous 2000 years were hasty in thinking the planetary orbits circular. Prof. Hanson calls this kind of intellectual process "retroduction". "A theory is not pieced together from observed phenomena," he writes, "it is rather what makes it possible to observe phenomena as being of a certain sort, and as related to other phenomena. Theories put phenomena into systems. They are built up in reverse—retroductively. A theory is a cluster of conclusions in search of a premiss."

R. Taton's book, "Research and Chance in Scientific Discovery",[2] translated from the French, has also a number of things to say which bear on the puzzle of how discoveries are made. But, again, the answer to the question is not forthcoming; Taton, like Hanson, points out that the making of a discovery presupposes in the discoverer qualities of scientific insight and intuition. The examples of Kepler, of Galileo, and for that matter of Pasteur and his initial struggles with the French medical world, bear out Taton's comment that science always reflects the current preoccupations of the civilisation in which it operates. Kepler could hardly bear to set himself up as a single worker with the assurance to contradict the accepted wisdom of all his predecessors—even though his facts

supported his new ideas. Galileo found himself in opposition to religious belief that this earth must of necessity be the centre of the universe. Darwin's theories seemed intolerable to Bishop Wilberforce. Just at this moment, however, in our own day, the atmosphere of our civilisation is in some respects particularly propitious to the making of discoveries. In all the sciences, the great discoveries of the 20th century—the radical hypotheses of Einstein, Planck, Bohr, and de Broglie, of Heisenberg's "uncertainty principle", and Lee and Yang's overthrow of parity in physics; the new analytical tools and their applications in biology; and the jump forward in chemical theory—all these have tended to remove the resistances to new ideas with which workers in other times had to deal and make us particularly receptive to new theories. There is, perhaps, one respect in which the civilisation of our time, like that of Galileo's Italy, may offer resistance. This is, if any new theory should seem to cast doubts on the rightness of what we today consider to be the objective scientific attitude itself.

DOUBLE-TALK

There is perhaps just a possibility that this may occur. In physics we are now accustomed to the coexistence side by side of the wave theory and the particle theory. The classical particle theory has as its starting-point the conception of the "punctiform mass', that is, that a photon or an electron possesses a mass situated at some Euclidian point, which, as we know, is a position without length, breadth, or thickness. De Broglie, on the other hand, has demonstrated that a wave motion at a geometrical point is inconceivable and hence photons and electrons must "spread". Prof. Hanson points out that the fact that we have learnt to live with these two conceptions simultaneously may also imply that we must do the same in a number of other contexts. For example, just as the language and mathematics of waves are different from those of particles, so is the language describing men different from that describing cells. Now men are made of cells. But while it is true to assert that men have brains, personalities, and financial worries, this sort of language is inappropriate for cells. "It has schizophrenia and an overdraft" is not an intelligible statement about a cell. We therefore arrange in dealing with the scientific problems of man to use simultaneously two languages, that applicable to patients and that applicable to cells, just as the physicist considering a single entity may deal with it at one time as a particle and at another as a wave.

The new discoveries in science come from new ways of looking at familiar facts. It may therefore happen that just as there are distinct languages for cells and for the animals made up from individual cells, a third scientific language may be needed in order to make the discoveries not yet discovered, but so badly needed, for the social groups composed of individual men. Be this as it may, Dirac's theory of 1928 was conceived to co-ordinate a mass of observation on electron spin and much else floating loose in physics. In the same way, Einstein's theory of general relativity explained the anomalous behaviour observed for the planet Mercury, which had vexed Newtonians for years. And Newton in his turn produced the theory of universal gravitation to give coherence and integrity to the three apparently distinct and independent laws of Kepler.

Prof. Hanson quotes Wittgenstein, "Though the aether is filled with vibrations, the word is dark. But one day man opens his seeing eye, and there is light." Taton takes rather a different attitude. He quotes Jacobi's criticism of Fourier for trying to persuade scientists to be "useful" rather than spending their time on theoretical research. "It is true that M. Fourier believes that the chief aim of mathematics is its public usefulness and its explanation of natural phenomena," he wrote, "but a philosopher like him ought to have known that the sole aim of science is to do honour to the human spirit, and that in this respect a question about numbers is as important as a question about the system of the Universe."

BE BOLD OR BE CAREFUL

But Taton, like Hanson, returns to the essential problem of how new hypotheses are arrived at. Poincaré, he points out, possessed a much wider mathematical background than Einstein, then a young assistant in the Federal Patents Office at Berne. Perhaps it was that he lacked what Einstein possessed, profound intuition of the nature of physical reality and an exceptional courage of mind. It is a curious paradox that the kind of thinking best suited to the verification of an existing hypothesis, the type of mind which can most effectively collect accurate data, perhaps indeed the sort of training most assiduously taught as "scientific", and the kind of precise writing most popular with the editorial committees of scientific journals may be least adapted to the making of those bold intellectual leaps by which new discoveries are made.

It is possible to buy "How to become a millionaire before you are forty" at a railway bookstall, although it is doubtful whether the author would be found to have succeeded from his own advice. Similarly, it is easy to follow the line of thought by which Kepler, or Newton, Pasteur, Einstein or Fleming made their discoveries. Knowledge is required, a good mind, conceptual boldness to follow where the facts lead, and a true understanding of what the facts are regardless of the words or symbols in which they are wrapped. But besides all this, the thinking that leads to the really new discoveries must contain an element of intuition. Darwin, in his autobiography, wrote:

> "In October 1838, that is, fifteen months after I had begun my systematic enquiry, I happened to read for amusement Malthus on Population, and being well prepared to appreciate the struggle for existence which everywhere goes on from long-continued observation of the habits of animals and plants, it at once struck me that under these circumstances favourable variations would tend to be preserved and unfavourable ones to be destroyed."

But a difficulty still remained, and about this he wrote: "I can remember the very spot in the road, whilst in my carriage, when to my joy the solution occurred to me."

What can the author of "How to Become a Scientific Discoverer" advise about this sort of thing?

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[1] Hanson, N. R., "Patterns of Discovery", Cambridge University Press, 30*s*.

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GEOPHYSICS

Compiled by ANGELA CROOME

Three-Mile Bore Beneath Ocean Floor?

The U.S. National Academy of Sciences in October formed a committee to consider the feasibility of boring down 3 miles or more to the Mohorovicic discontinuity beneath one of the deep oceans of the world. The discontinuity generally known as the "Moho" is a layer in the Earth's outer structure thought to mark the transition from the hard outer rocks of the globe, the "crust", and the semi-plastic highly compressed rock of the "Mantle". The Moho is not well understood; its effect on the passage of seismic waves is anomalous.

The reason for attempting such a bore under one of the oceans is that in these areas the crust above the "Moho" is thought to be only 3 miles thick and consisting of basaltic material; the continents superimpose a 25-mile-thick granite layer above this. To offset this advantage, however, there is the difficulty of boring into the Earth's crust from a platform floating in deep water. Up till now the oil companies have succeeded in driving drills through 1500 ft. of water. Land-based oil-rigs have attained a record depth of 4 miles recently in Texas. There is obviously a considerable difference between carrying out a 4-mile-deep drill on land and doing it after first passing through 3 miles of water. It is no use attempting to make such a bore-hole in coastal waters as there would still be a substantial amount of granitic outer crust associated with the near-by land-mass to penetrate. It is clear that any drilling rig to be used must be mounted on a bobbing platform. The cost is likely to be enormous, a figure of $20 million has been mentioned as a preliminary assessment.

Nevertheless, scientists consider that the rewards in knowledge would also be vast and justify the effort. Findings are likely to include a complete history of the Earth's climate, clues to the origin of the Earth itself and much data on the evolution of life.

Antarctic Developments

On December 14 a party of eighteen Russians travelling in four snow-tractors reached the vicinity of the **Pole of Relative Inaccessibility** and set up a station Inacessibility at 88°6′ S, 55° E. This may be taken as the climax of the Russians' IGY achievement in the Antarctic; they have been struggling towards this goal since they started operations three seasons ago. They have been delayed by a variety of factors, including the difficulty of reaching intermediate positions, the great altitude and the soft-snow conditions that have been encountered.

The party covered the 1360 miles from Mirny in 52 days and were closely supported during the earlier marches by aircraft. On the way they encountered temperatures as low as −76°F and found themselves frequently travelling above 10,000 ft., which made breathing difficult.

The Inaccessibility Pole station is at a slightly lower altitude than had once been expected. It has been given both as 11,500 ft. and 12,170 ft. above sea-level. This still makes it as high as the highest Antarctic permanent station, Sovietskaya.

Inaccessibility will be used solely as a summer station. During the remainder of this season scientific observations will be carried out, including those in actinometry and glaciology and seismic soundings. At the approach of winter the party will withdraw north. Next season the station will be reoccupied for a summer science programme and it will also be a staging point in the 3000-mile Antarctic crossing that the Russians plan to make from Mirny to the coast of Queen Maud Land, where a new station, Lazarev, will be set up this season.

Belgians Rescued: What might have become a very unpleasant situation was saved by the timely arrival of a Russian light aircraft in the Queen Maud Land area in December. Commandant Gaston de Gerlache, leader of the Belgian Antarctic Expedition, and three companions were travelling 250 miles inland from their coast base, Roi Baudouin, when their Auster aircraft crashed in the crevassed area of the Crystal Mountains. This occurred on December 6. On December 14 the Russian aircraft was in the area of the crash, having flown in from Mirny with a refuelling stop at Mawson. They spotted the crashed Auster and landed near it but found it had been abandoned. The crew had left it six days after the crash and started to walk to a Belgian stores dump 80 miles away. They had left a note in the aircraft to this effect. By the time the Russians reached the Auster the Belgians were expected to have food for only two more days. On December 15 the Russian aircraft located the Belgian party and rescued them. Apparently none of the party was any the worse for their experience. The sequence of events recalls the accident that befell a reconnaissance party of three belonging to the Trans-Antarctic Expedition during the 1956–7 season, also without fatal consequences.

Nuclear Power in Antarctica: The United States Government has approved the construction of a nuclear power plant within the next two years at McMurdo Sound, Rear-Admiral George Dufek, naval commander of Operation Deep-freeze, revealed recently. The reactor is expected to cost between $4 and $5 million (£1,400,000 or more) but should pay for itself by the saving made possible in fuel in three years.

The reactor envisaged for McMurdo Sound is likely to be one of the small packaged type developed by the United States. It is of interest that a power reactor is currently being built at Fort Greely, near Fairbanks, Alaska, at a cost of about $5 million. Its output is rated as 17,000 thermal kW. The saving in diesel fuel annually is reckoned as 3,480,000 gallons.

There have also been hints of providing the Americans' Byrd station with a nuclear power reactor. This would be a small "packaged" reactor capable of being transported in a DC-3 aircraft to the station.

Chugunov Island: More details are now available of the island that the Russians claimed to have discovered in the Antarctic earlier this year. It was first sighted during an aerial photo-survey off the Shackleton ice-shelf in 1956. Last April (1958) a landing was made and it was named Chugunov after one of the Russian expedition members who perished in the Antarctic. The island is situated at 65° 58′ S, 99° 21′ E, and consists of an ice-dome with moraine outcrops.

Italian Expedition: A small Italian expedition to the Antarctic was scheduled to leave in a 150-ton schooner in October last. The expedition has been organised by the Instituto Geografico Polare and has had help from a number of Italian firms, including Olivetti, Palmolive, and Motta. The party will consist of only twelve men, five of these being scientists. The intended site for the station is on Cook Peninsula, off Queen Maud Land.

German Expedition: This project has now been postponed until 1959 owing to difficulties in chartering a ship. The

Kista Dan will be chartered for next season and take the party off in the Antarctic spring of 1960. The proposed destination is a site on the coast of Newschwabenland, between 3° and 7° W. The leader and initiator of the expedition is Dr Karl Herrligkoffer.

Polish Expedition: The Polish Academy of Sciences has come to an agreement with the Soviet Academy of Sciences whereby a group of Polish scientists are to take over the "Oasis" station in the Antarctic. They embarked aboard the *Mikhail Kalinin*, one of the three Russian relief ships, from Gdynia in December.

"Oasis" was the second station to be established in the Antarctic by the Russians, in October 1956. It lies near the coast in an ice-free area with fresh water lakes called the Bunger Oasis, after the American who first discovered this Antarctic curiosity. It has been operated as an additional substation to the main Russian IGY stations ever since. It has proved fruitful for micro-climatological studies in particular. "Oasis" is about 224 miles from Mirny.

Six Poles are to form the party and it is led by Eng. W. Krzeminski. Initially the scientific work will cover gravity, geomagnetism, earth-tides, seismological studies, the CO_2 content of the air, and atmospheric radioactivity. Next season a further group of eight or ten scientists will go to "Oasis" to make ionospheric and special meteorological studies. A factor in deciding to hand over this station to the Poles is that it lies on the same longitude as the Polish IGY station of Cha-Pa in northern Vietnam (see DISCOVERY, 1957, vol. 18, No. 7, p. 310).

Flatter at the Top

Prof. N. A. Kozyrev of Pulkovo Observatory, has just given details of another remarkable observation. He has found that the Earth and some of the other planets are flatter at the top than at the bottom—at the northern hemispheres than at their southern hemispheres. He attributes this to certain "unknown" forces acting along the axis of rotation of spinning bodies, which causes a different degree of compression at opposite ends of the axis. He has already measured the hemispheres of the rapidly rotating planets, Jupiter and Saturn, against each other and found that they show a similar asymmetry to that of the Earth.

Measurements have been carried out in the Arctic and Crimea using methods suggested by Kozyrev which established the existence of these forces. These measurements have shown conclusively the dependence of the forces acting along the axis of rotation with geographic latitude. In fact it is Kozyrev's opinion that these forces must be of such magnitude and change so fast in the polar regions that they could be used as an alternative or additional means of fixing geographical position.

It is thought by geophysicists in this country that if this flattening at the top applies to the Sun also it will be of the greatest interest. Certain unexplained anomalies are apparent in the progress of sunspots across the solar disc during the 22-year-solar cycle; these could well be accounted for if the Sun's northern and southern hemispheres did not quite match.

SPACE RESEARCH

The Russian *Lunik*

Patrick Moore, F.R.A.S.

The Russian lunar probe, launched on January 2, popularly and aptly known as the *Lunik*, is in every way a technical triumph. The Soviet scientists who made it possible have well earned the congratulations which have been pouring in from all over the world. It is a hopeful sign that these congratulations come not only from foreign scientists, but from heads of States; the messages from Mr Macmillan and President Eisenhower, in particular, have received wide publicity in the Russian Press.

Official statements from Moscow make it clear that manned flight to the Moon is now regarded as practicable, and it is said that an attempt will be made during the next few years. This may well be so; technical development is now so rapid that it is difficult to make forecasts. On the other hand, it is only wise to be cautious, and to sum up the whole position without falling into the trap of over-optimism.

As yet, certain points with regard to *Lunik* itself are far from clear. No preliminary warning was given to Prof. Lovell and his team at Jodrell Bank; and though the radio telescope there was eventually taken off its regular programme in an attempt to track *Lunik*, valuable time had been lost, with the result that no contact was made. This lack of advance warning is decidedly curious. So far as is known, the Russians do not possess a "dish" type radio telescope equal to that at Jodrell Bank, and neither is there a comparable instrument in America. Moreover, the Russians themselves lost contact with the probe during the time when it was below their horizon, and the collaboration of the British team—which would have been freely given—would have been of great value to them.

Secondly, it is now clear that the transmitters carried by *Lunik* were able to maintain contact only for a very limited period. At 7 a.m. GMT on January 5, the Tass Agency announced that all contact had been lost. This was a mere sixty-two hours after the launching; the probe was then approximately 370,000 miles from the Earth.

Thirdly, the Russians stated that no attempt was made to put *Lunik* in orbit round the Moon. This manoeuvre would admittedly lead to complications, but as matters stand the probe is now lost for ever; it has entered an orbit round the Sun, and though it should return to within a few million miles of the Earth during the next five years, the chances of its being detected again are slight. It is extremely difficult to keep track of a body whose mass is, on the astronomical scale, negligible. This is demonstrated by the fact that some of the interesting small asteroids which have made relatively close approaches to the Earth have been permanently lost and will hardly be recovered except by sheer luck.

Since it is clear that the Russian launchers are extremely efficient, it seems in fact that they have not made the maximum use of their first *Lunik*; by giving advance information, by installing more efficient transmitters, and by attempting to put the vehicle in orbit round the Moon, more facts could have been gathered. This does not, however, affect the magnitude of the achievement. The Russians have done what the Americans have so far failed to do, and what no other nation has even attempted to do; no praise can be too high for the Soviet scientists. It may even be that this was merely the first of several experiments, and that it proved to be more successful than the Russians had hoped. In any case, important developments are certain to follow very shortly; further probes will carry on from where *Lunik* left off.

There are certain experiments which can be carried out only by using rockets of the *Lunik* type. For instance, is the Moon associated with a belt of intense radiation similar to that recently detected above the Earth? Since there is considerable evidence that the Moon's magnetic

field is very weak, if it exists at all, such a belt is rather improbable, but it is much too early to be certain. It will, moreover, be interesting, though by no means so important, to send a vehicle on a "round trip" to gain information about the 41% of the Moon's surface which is always turned away from the Earth, and which we can therefore never see so long as we have to make observations from our own world. This was one of the tasks allotted to *Pioneer*, the American probe which reached a distance of 79,000 miles from the Earth before falling back into the atmosphere.

It is often stated that from a purely scientific point of view, manned space flight is not of primary importance, since in many ways instruments are superior to human observers—and, moreover, lack many of the human frailties. There is something to be said for this attitude, but on the whole it is difficult to maintain, and the Russians clearly do not agree with it; over and over again they have stressed that it is their intention to send men to the Moon as soon as possible. *Lunik* is simply a part of this programme.

Unfortunately, we have to admit that we are still some way from true space travel. It is one thing to send an unmanned probe-rocket on a one-way trip, but it is quite another to send a human crew to the Moon and ensure a safe return. Of the many problems to be faced, three stand out prominently: fuel, radiation hazards, and re-entry into the Earth's atmosphere. *Lunik* has undoubtedly made substantial contributions to the first two of these problems, even though we have so far little positive information about the instruments carried; but not to the third. Both the Russians and Americans are making an intensive attack upon the re-entry problem, but so far there are no indications that it has been solved. Until that time comes, manned space flight is out of the question. It is thus premature to say that the lunar probes open the way to interplanetary travel.

What of the immediate future? Before long it is probable that unmanned rockets will land upon the Moon, and this too is an essential preliminary, since as yet we are far from certain as to the precise nature of the lunar surface. Other vehicles will be sent into circum-lunar orbits, and attempts will be made to launch rockets and bring them back to Earth undamaged. When all this has been accomplished—not once, but on numerous occasions—it will be time to think about sending men to the Moon. *Lunik* represents an important first step.

There is one extra difficulty which is all the more deplorable because it is of our own making. A launcher which can send an *Explorer*, a *Pioneer*, or a *Lunik* into orbit may also be used to launch a weapon of destruction, and this military complication means that scientists are not free to exchange their results and ideas. The result is inevitable duplication and delay. At the moment there can be no doubt that the Russian propellants and techniques are far superior to the Americans'; on the other hand, it is probable that American instrumentation is better than the Russian. Britain, too, has made definite contributions, despite our failure to launch a space probe of our own. If all these results could be combined, the work of the scientists would be far easier.

We can only hope that common sense will prevail and that scientific discoveries will be put to their proper use. Meanwhile, Russia's *Lunik* is in every way a splendid achievement. Even if it has not opened the road to the Moon, it has helped to break down some of the last barriers.

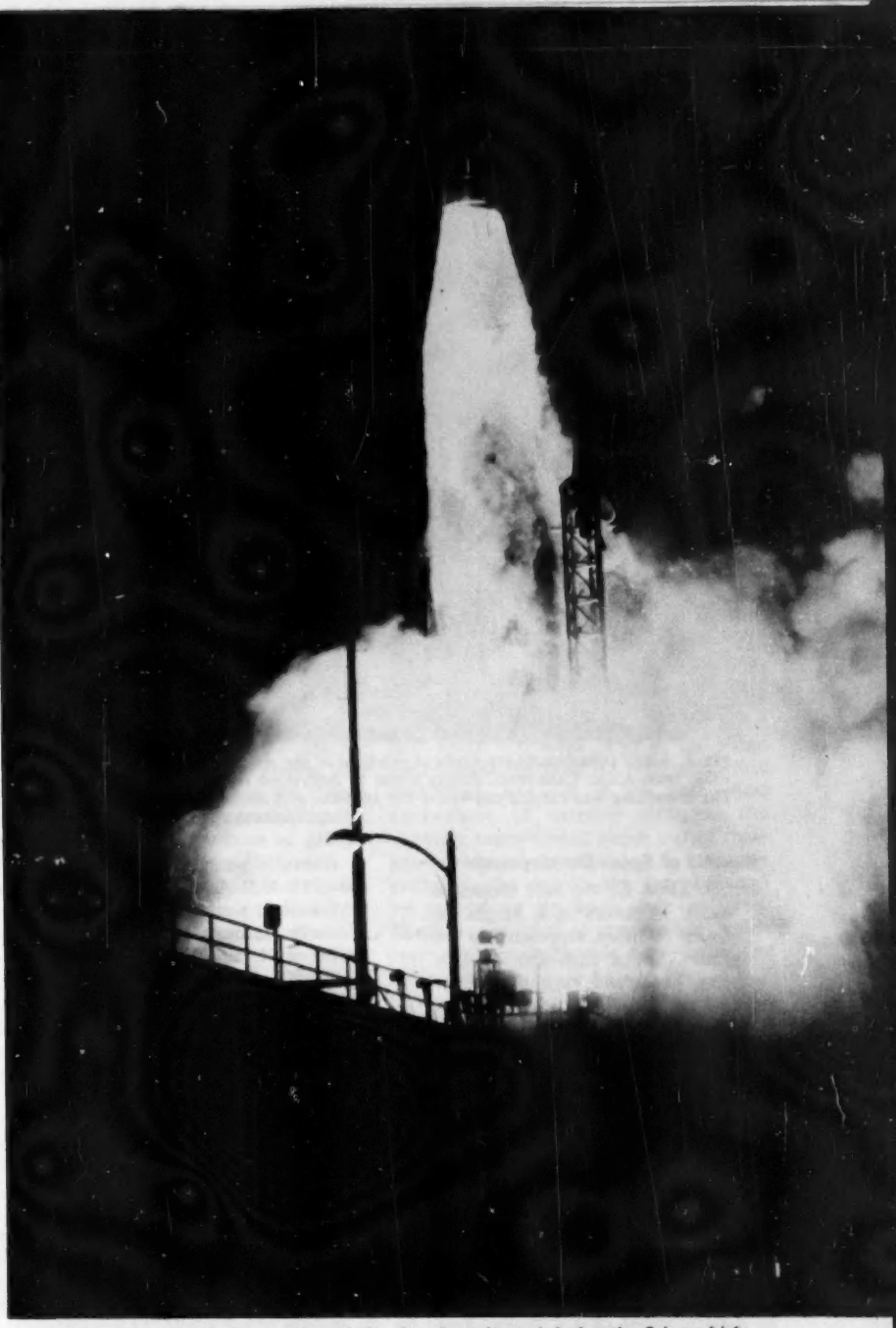


FIG. 1. The U.S. Air Force *Atlas* missile rises from its pad during the firing which launched it into successful orbit during a test to determine its satellite launching capability and to test the launching technique. The successful launching was carried out under the auspices and authority of the Advanced Research Projects Agency of the Department of Defense.

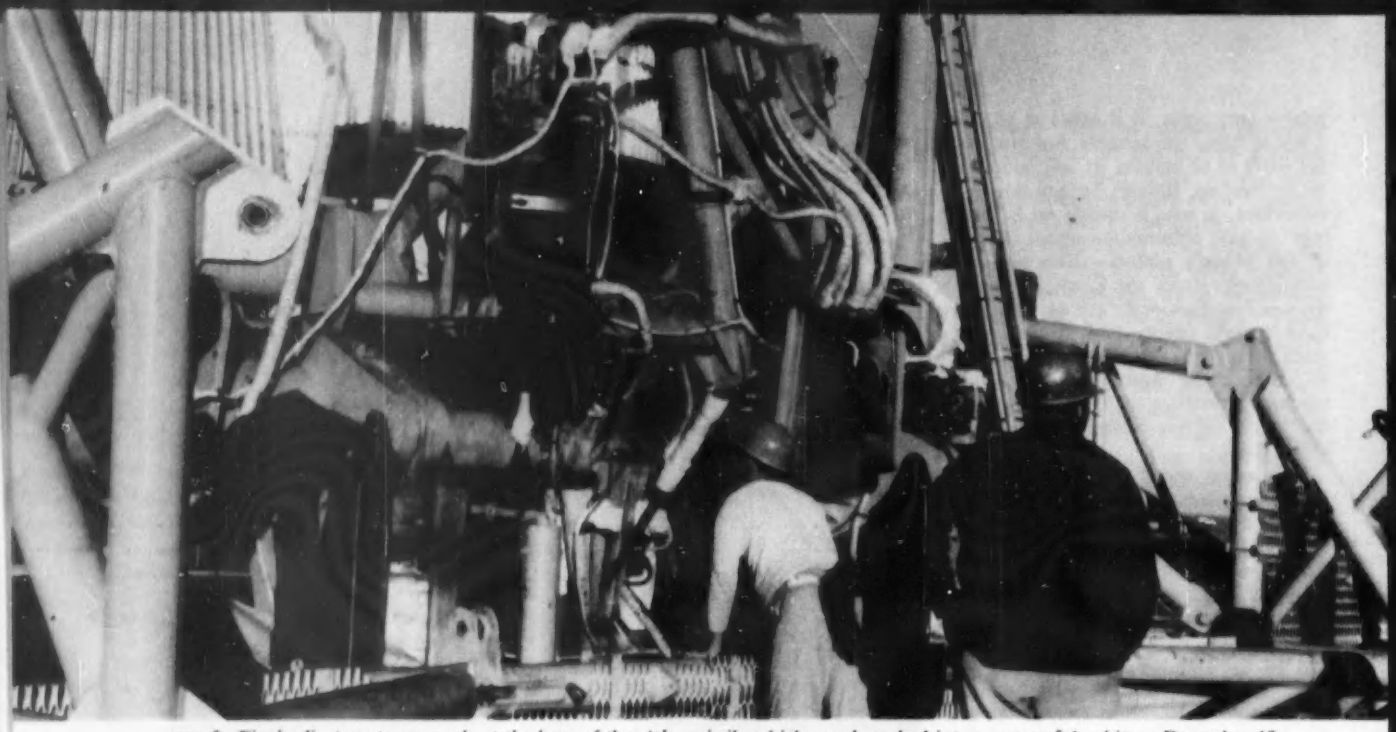


FIG. 2. Final adjustments are made at the base of the *Atlas* missile which was launched into a successful orbit on December 18, 1958, from Cape Canaveral, during a test to determine its satellite launching capability and to test the launching technique. The launching was carried out under the auspices and authority of the Advanced Research Projects Agency of the Department of Defense of the U.S. Air Force.

Resumé of Space Developments

Oct. 9: Lieut. C. McClure remained nearly 24 hours at a height of almost 20 miles, suspended in the gondola of a high-altitude balloon. Heat and humidity in the cockpit forced him to descend earlier than planned.

Nov. 8: Third and last U.S. Air Force Moon-shot which failed before leaving the Earth's atmosphere.

Dec. 4: Presumed date of the end of *Sputnik III* rocket. There is some evidence for thinking this may have been in vicinity of Australia.

Dec. 6: First U.S. Army Moon-shot, using a *Juno II* combination rocket. The rocket reached 65,654 miles up, some 7000 miles less far than the second Air Force effort in October. Cause stated to be insufficient acceleration, its maximum speed was 23,990 m.p.h., and an error in launching angle of about 3°. Instruments: Two Geiger counters for measuring the Van Allen radiation. Payload weight: 12·95 lb.

Dec. 13: U.S. Army fired a squirrel monkey to a height of 300 miles in the nose-cone of a *Jupiter* missile. It is not known whether the monkey survived re-entry since the nose-cone was lost in the Atlantic. The monkey showed "no adverse physical effects" during other stages of the flight.

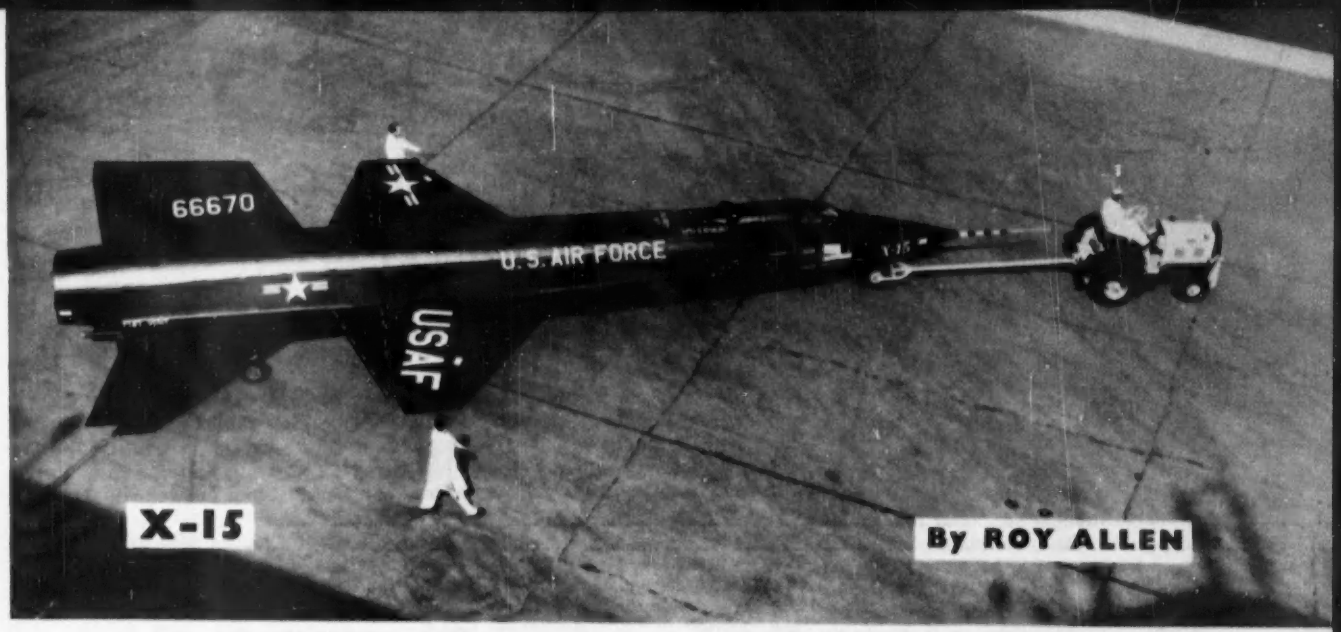
Dec. 19: U.S. Air Force successfully launched a complete *Atlas* ICBM rocket into an orbit varying between 115 and 920 miles from the Earth. Orbiting weight: about 8600 lb. or nearly 4¼ tons. Payload: 150 lb. Named SCORE for "Signal Communications Orbit Relay Experiment", the rocket carried a tape-recorded goodwill message from President Eisenhower. Later this message was erased from the tape on command from the ground and another message recorded for relay on command as the rocket passed overhead. This pioneers the way for a new method of long-distance communication, relieving the pressure on the short-wave bands. Lifetime in orbit: about 5 weeks, that is until January 21.

Volcano on the Moon?

In November, Prof. N. A. Kozyrev, while working at the Crimean Astrophysical Observatory, claims to have witnessed a volcanic eruption in the Alphonsus crater of the Moon. This is of the greatest interest since it has for many years now been thought that the Moon was completely "dead" and that the craters which pit its face were due to the impact of meteors which could impinge directly upon it without suffering the destructive effect which our atmosphere has upon all but the largest meteorites. It now seems that there remains at least some vestigial heat and life within the Moon, though probably the lunar craters are of mixed origin, some due to volcanic activity and some to the impact of meteors.

Prof. Kozyrev observed visually with the 50-in. reflector of the Crimean Observatory between 3 o'clock and 3.30 a.m. on November 4 that the central peak of the Alphonsus crater became blurred and appeared to be engulfed in a reddish cloud. At the time Prof. Kozyrev was taking spectra of the Moon using exposure times of half an hour. When the plates were developed the spectrogram relating to this half-hour period distinctly revealed a whole series of so-called Swan Bands of the carbon molecule in the emission. This corresponds with what would be expected if there was an escape of considerable quantities of heated carbon gas from the Moon's interior. The spectrogram taken during the following half-hour gave no sign of this emission of carbon.

Close study of the Alphonsus crater during the parts of the next two months when it again became visible, has shown no sign of disturbance there. This, of course, proves nothing. Astronomers in other countries, while at first sceptical, have since tended to come round to a rather cautious agreement with the interpretation that Prof. Kozyrev has put upon his observations.



X-15

By ROY ALLEN

In a few months the United States Air Force will launch another research vehicle to find out more about space. The difference with this machine, though, is that it will be the most advanced of its kind to fly, and more like a manned satellite than anything that has yet been launched.

The vehicle is North American Aviation's X-15 (see fig. above), which has been under development since December 1955 to answer the need for an aeroplane that could provide data and information on manned flight outside the atmosphere, yield further facts on such aspects of flight as stability and control at extreme altitudes, and aerodynamic heating.

The X-15 is by no means a "manned satellite", for it will neither orbit nor be sent completely into space, but it will take pilots to the fringe of space and enable much to be learned about conditions prevailing there. Its operational height will extend to 100 miles, which will give investigators plenty of scope.

The X-15 looks strange, but is no stranger than some of the vehicles being produced by both the West and the East for investigations into space flight. The Russians have doubtless got similarly advanced machines in various stages of development for their space-flight programmes. If more were revealed, it is likely that the Americans and Russians would find they were working on very similar lines.

But the X-15 is particularly important to the West, for it is the first aircraft to be built for the purpose of taking a man to these extreme altitudes and bringing him back safely to tell of his experiences. Like the early Bell X series of rocket-powered aeroplanes, the X-15 was initiated for the co-operative research programme managed jointly by the NACA (now the National Aeronautics and Space Agency), the USAF Air Research and Development Command, and the U.S. Navy Bureau of Aeronautics. During the summer of 1954 these bodies held their first meeting to discuss the design and manufacture of an aeroplane capable of investigating the new field of piloted flight at extreme speeds and altitudes. A competition was launched for this aircraft in December of that year, and twelve months later North American Aviation was announced the winner and was awarded a contract for the construction of three aeroplanes. Reaction Motors (a division of Thiokol Chemical Corp.) was named as the prime contractor for the rocket motors.

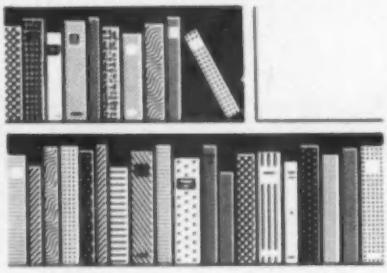
Since then North American Aviation have been model-testing and building the first aircraft, which was unveiled last October. In appearance the aircraft they have produced is a missile-like device with a fuselage twice the length of the span of the wings—50 ft. and 22 ft. respectively. The height over the wedge-shaped tail is 13 ft. The wing area is 200 sq. ft. (that of the Spitfire was 242 sq. ft.).

Otherwise the X-15 is fairly similar in appearance to other modern high-speed aircraft, but it has many unique features. One of these is the vertical tail, which has a trailing edge thickness of no less than 12 in. The upper half of this fin is pivoted to provide control over yaw at high speeds. Aerodynamic stability is also maintained by a small ventral fin, which is jettisoned for landing. Another feature of interest is the long fairings on either side of the fuselage, which serve a dual purpose: apart from housing control runs and services, for which space in the fuselage is limited, they help to minimise airflow interference between the wing and fuselage, which at high speeds (the X-15 is designed for up to Mach. 7·0) can be exceedingly dangerous. A further feature of great interest is the system of control jets, which are fitted both in the wings and around the nose, to provide control over pitch and roll in the near-airless atmosphere of extreme altitudes. By shooting super-heated steam out of these jets—produced by catalysed hydrogen peroxide—the nose of the aeroplane can be pushed up or down and the wings tilted as required to maintain a stable course in air that would be too thin for orthodox controls to be effective.

The X-15 is built of steel and titanium, with an outer skin of Inconel X, which is said to be able to withstand a temperature of 1000°C. It has been said that beryllium is also used.

For its flights, the X-15 will be taken to 40,000 ft. by a Boeing B-52 bomber, whereupon it will be air-launched and the 50,000-lb.-thrust liquid fuel rocket motor lit for a brief six minutes of operation. During this time, however, the X-15 will gain sufficient speed and momentum to fly on a near-ballistic trajectory to 100 miles' altitude, where it will remain for an even briefer period before gliding at hypersonic speed back to the denser atmosphere and to land at a gradually reduced rate. For the landings, which will be made at Edwards Air Force Base in the Mojave Desert, small skids will be extended from the rear fuselage to preserve stability after touch-down. A braking parachute will be employed to slow the aircraft, which lands at about 200 miles per hour.

The pilot on the first flights will be Scott Crossfield of North American Aviation. Later, Captain Robert A. White of the USAF will make the first "maximum performance" tests. This man, it is likely, will be the first to fly on the fringe of space.



THE BOOKSHELF

The Science of Photography

By H. Baines (*London, Fountain Press, 1958, 309 pp., fully illustrated, 38s. 6d.*)

The publication of this book is a major event in the history of photography. Dr Baines has set out to help the intelligent photographer who wishes to find out something about the theory on which his practice is based. Although it should be stated at once that the author has succeeded in his primary aim, the book will come to be the foremost text not only for those who wish to become professional photographers, but also for those scientists who have come to realise that a proper understanding of the photographic process must precede the full exploitation of all the possible applications of photography in research.

Every aspect, from the manufacture of emulsions to their exposure and processing, is discussed in a logical sequence; each chapter is built on the information contained in the preceding one. Wherever necessary, a brief section on basic science is included. This, however, is clearly marked, so that it can be ignored by those who are already familiar with physics and chemistry. Whilst it would be impossible to write a textbook in the style of a novel, Dr Baines has clearly mastered the difficult art of clear explanation without over-simplification. The exposition of the theories of latent image formation and of development are particularly well reasoned and lucid.

It could be argued that a curtailment of the section on emulsion-making and -coating would create the necessary space for a more extended discussion of photographic optics, which, at present, is accorded a mere eleven pages.

The diagrams are a valuable part of the book. Although some are separated from their text, most appear on the same page. It is interesting to note that they are frequently inserted above the text which refers to them. The reader is thus spared the annoyance and waste of time normally experienced by the search for illustrations. Although doubtlessly more expensive, the appearance of many diagrams could be improved by replacing stencilled letters and numerals by typesetting.

Whilst it is clear that the present publication is an understand-what-you-are-doing book and not a how-to-do-it text, even the brief concluding chapters on applications and on possible future developments are devoid of references. Many readers, particularly those who merely wish to use photography as a tool in their work, might welcome a selected list of books and original papers which would guide them from the freshly acquired knowledge of theory to the practice of routine and specialised techniques and, above all, to applications which, though possibly evolved in some other field of science, might prove of value in their research work.

Dr Baines and the Fountain Press, however, should be congratulated on the addition of an undoubted classic to the photographic literature. C. E. ENGEL

The Russians in the Arctic

By Terence Armstrong (*Methuen & Co., 1958, 22s. 6d.*)

From time to time we catch faint echoes of great things being done in the Arctic by the Soviet administration: weather stations all along the Siberian coast, scientific stations far out on the drifting ice, rich finds of minerals, and thriving colonies of Russians well inside the Arctic Circle. That we know very little about them is the fault, or the care, of the Communist Government and its policy of secrecy.

Dr Armstrong has cleared away some of the mist by piecing together what has trickled through the Iron Curtain concerning some of these developments. He has done it with shrewd and balanced judgment and in an honest endeavour to see the Russian point of view. The book is concerned with a variety of topics, some of which will be new to the ordinary reader. Such, for instance, is the story of the German raider, *Komet*, which, helped by Soviet ice-breakers, did the North-East Passage in three weeks in 1940, to pursue an adventurous career in the Pacific, where she sank ten Allied ships.

There is a chapter on the development of the Northern Sea Route by the Russians, on which the author is our leading authority, and another on their High Latitude expeditions by air and their stations on the drifting ice, gathering a wide variety of scientific data, of which the meteorological observations are allowed to come into world circulation. With this chapter there is an astonishing map showing the extent of the Russian work in most of the Arctic Ocean which in itself is sufficient proof of the author's assertion that the Russians lead all other nations in their scientific coverage of the problems of the Arctic.

There is a résumé of what the Russians are doing with the backward peoples of the Siberian Arctic. It seems to boil down to looking after these tribes but ensuring that they shall become good communists and shall not be too impatient with the Russian colonies that are being established in their midst. The book includes a brief but fascinating account of the woolly mammoth which once haunted those regions. Though he died up to 20,000 years ago, the Arctic climate has preserved his remains so completely that, once in a while, a corpse is uncovered which is still just edible for wild animals, for the hungry tribesmen, and, once, to furnish a doubtful dish for a party of explorers at a dinner in New York.

In a final chapter we have the conclusions of the author as to the value to Russia of the great efforts they are expending on their Arctic. Yet he is as puzzled as his readers will be as to why a great part of the Arctic Ocean should be sealed off from all other nations and the land be declared a more forbidden territory than ever was Tibet. There seems to be no limit to what imperialism, colonialism, and dictatorship under the cloak of a narrow ideology can get away with in modern times. F. DEBENHAM

A Survey of Science

By Max Petterson (*London, Science Club, 1958, 37 pp., 7s. 6d.*)

This comprehensive outline is intended to be used as a guide in connexion with general science courses in sixth forms, technical colleges, and universities. It is designed to provide a framework around which teachers may build their courses, and to give specialist as well as general science students an overall view of the major developments in science and technology and their relation to human society. A supplementary reading list is provided at the end of each chapter.

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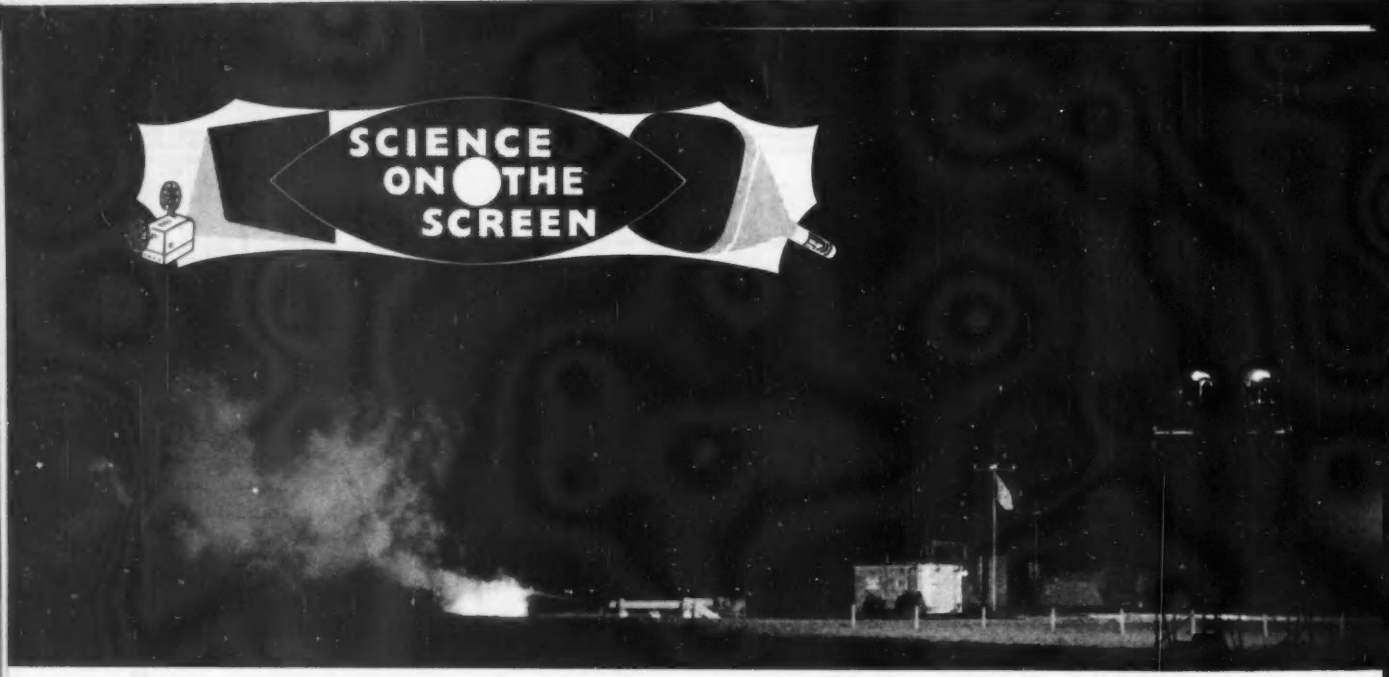


FIG. 1. **Breakthrough.** An hour-long BBC television programme on the exploration of space by rockets and satellites which was broadcast on November 12.

One of the features of the programme was television's first visit to the Rocket Propulsion Establishment at Westcott, Buckinghamshire, where BBC viewers saw the firing of the *Raven* rocket. Note the television cameras mounted on the temporary scaffolding.

Television

As the year ended science television was not given much programme time. We did have a "Science is News" broadcast from BBC on November 27 and another on December 11. The first of these began with a film of a photoelectric sorting machine, and then led on to an interview between Dr Margerison and a biologist, Dr Grey-Walter, about feed-back models. The subject under discussion was that curious boundary-land in which attempts are being made to find some analogy or relationship between animal behaviour and feed-back mechanisms. There were one or two, perhaps too optimistic accounts of how some experimental feed-back mechanisms were reputedly reproducing human brain activities. It is certainly too early to be dogmatic here. The broadcast was of interest but a little lame and purposeless.

There followed a short film on the behaviour of bees, and this was just beginning to be of interest when we were taken across to a consideration of the engineering problems associated with a new project under discussion for digging a 10-mile bore-hole through the crust of the earth (4 miles has already been reached before). The subject was most ably reported. The many technical terms which cropped up were carefully and clearly explained, and indeed the programme contained a very real solid core of geophysics. A good informative broadcast.

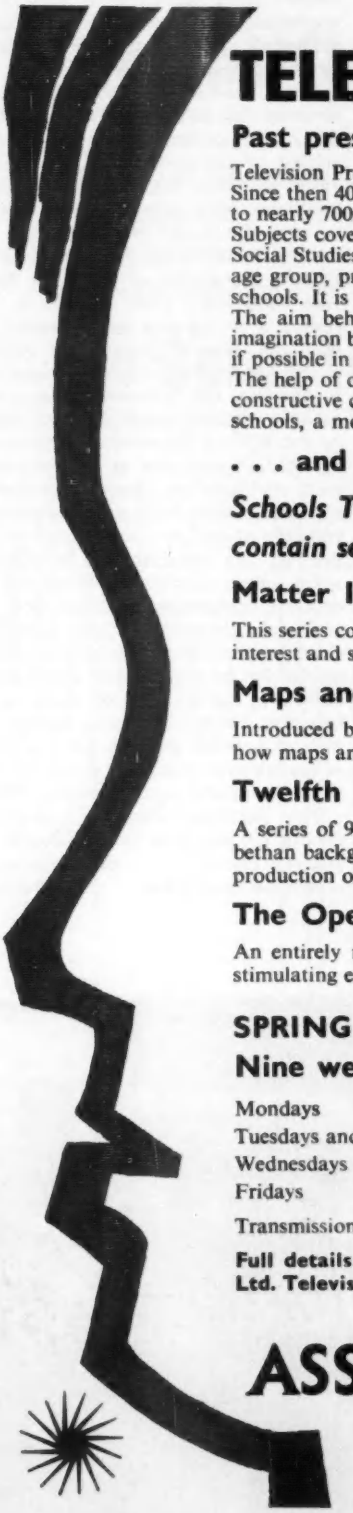
Eye surgery, and in particular corneal grafting, was the next subject. This was a combination of interview with an eye surgeon and well-selected film shots. The surgeon made a delicate and elegant operation seem very simple to execute. Attention was drawn to the storage of eye tissue, secured from the recently dead. This was a worthy broadcast on a noble and humane subject, that of restoration of vision to the blind, and it constituted a fitting conclusion to a very good half-hour. Perhaps the first subject treated was redundant: surely three subjects are more than enough.

The December 11 programme again started with Dr Margerison, who introduced some film illustrating the functioning of the electric grid system for load distribution. This led to an interview with Mr Casson concerning the scheme for the projected power cable across the Channel to link the British with continental grids. Film of cable-laying techniques occupied a prominent place and attention was drawn to the method of compensation of magnetic field to avoid influencing ship compasses. This was a relatively long session, almost 15 minutes, and although there was perhaps an excess of film, nevertheless we obtained an excellent perspective of the whole project and the reasons prompting it.

Next followed a most fascinating and concise account by Dr Newth about the recent successful methods for early sex determination in human pregnancy, which was supported by good diagrams. However, your reviewer is bound to admit that he thinks these researches less exciting than some may believe. The future mother will in any case soon know the sex of her, as yet, unborn child, and to most it is not going to be of much value to know the sex a few months earlier than birth. Indeed, on the contrary in some cases, possibly many, it may be very harmful. How well we know that the mother's first sight of her new-born child frequently compensates completely for disappointment as to sex. For a highly strung mother to know well in advance of an unwanted sex may well prove absolutely disastrous. However, such personal views have nothing to do with the excellent broadcast.

We were next treated to one of the most entertaining (yet instructive) periods we have yet seen on science television. The producer organised for us a discussion, or rather a conflict, on the subject of dental caries and tooth-pastes, a matter which affects us all, and many of us only too painfully. There were present three experts: a dental surgeon, who was more or less neutral and acted as chairman, who described with some enormous models the onset of caries, and reviewed theories as to the origin of the decay; then followed a scientific representative of a tooth-paste manufacturer, who quietly and modestly made a number of specific claims for tooth-paste additives as agents for fighting bacterial decay; the third member, a bacteriologist, went straight in to the attack and scathingly and witheringly discounted the value of any of the commercial additives. He demanded more fundamental research, not unproved claims, and he certainly did not mince his words.

This whole period, which lasted almost 15 minutes, was first-class live television,



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Television Programmes for Schools were inaugurated by Associated-Rediffusion in May 1957. Since then 400 programmes have been broadcast, and the audience has grown from 80 schools to nearly 700.

Subjects covered so far include General Science, Mathematics, English Literature, Geography, Social Studies, Visual Arts, and Music. Although presented mainly for children within the 11-16 age group, programmes are also used by primary schools, grammar schools, and independent schools. It is hoped soon to widen our aims to include these other audiences specifically.

The aim behind the presentation of any programme for schools is to stimulate the child's imagination by bringing into the classroom the real-life background and application of a subject, if possible in ways that the teacher alone cannot easily achieve.

The help of our Educational Advisory Council and the support of teachers, who send in many constructive comments and criticisms ensures, for the production of television programmes for schools, a most satisfactory co-operation between this company and the teaching profession.

. . . and for the future.

Schools Television Programmes for the Spring Term will contain several features of special interest:

Matter In Use

This series continues the year's work in General Science. Its main purpose is to catch the pupils' interest and subsequently guide their thinking along scientific lines.

Maps and Men

Introduced by an experienced Antarctic Explorer, this series brings maps to life. It will show how maps are used in many activities from flying to town planning.

Twelfth Night

A series of 9 programmes producing Shakespeare's play in costume, and examining its Elizabethan background, imagery and interplay of character. This follows the success of last year's production of Macbeth.

The Open Window—an Anthology for Television

An entirely new conception in programmes for schools. Television's remarkable power for stimulating enthusiasm will be exploited to encourage children to express themselves.

SPRING TERM 1959

Nine weeks from Monday, 19 January to Friday, 20 March

Mondays	Matter in Use	General Science	Age-range 13–15
Tuesdays and Thursdays	Maps and Men	Geography	Age-range 13–15
Wednesdays	Twelfth Night	English Literature	Age-range 12–16
Fridays	The Open Window	An Anthology for Television	Age-range 11–16

Transmission Times: 2.43 to 3.10. Each programme repeated daily from 3.23 to 3.50 p.m.

Full details are available from The Schools Liaison Officer, Associated-Rediffusion Ltd. Television House, London, W.C.2.

ASSOCIATED-REDIFFUSION

These programmes are also available in the areas served by: A.T.V. (Midlands), S.T.V. (Scotland), T.W.W. (S. Wales and the West of England), Southern Television, and T.T.T. (North East).

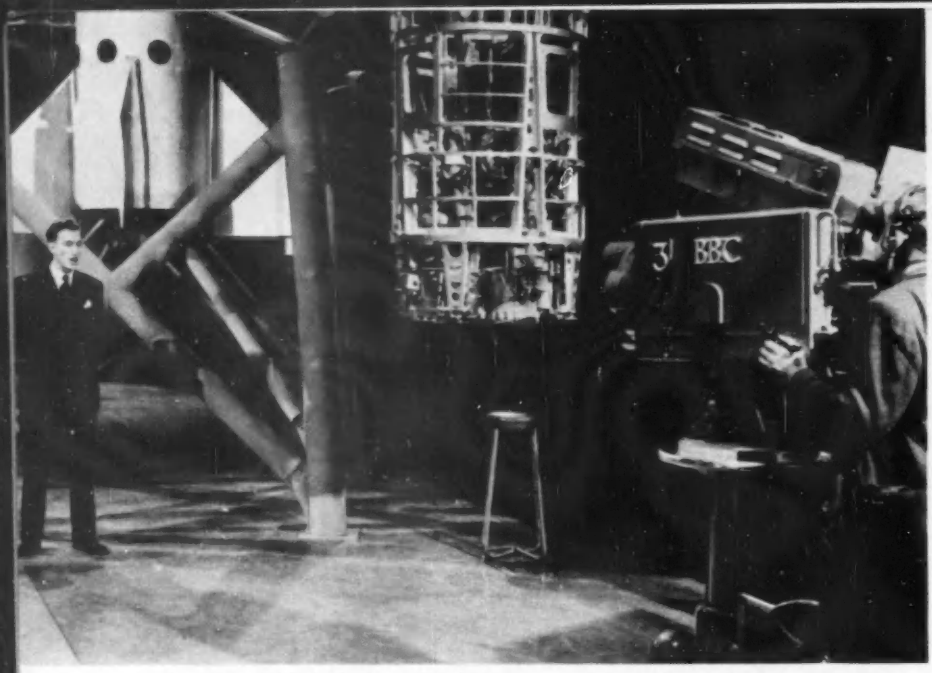

FIG. 2. (*Above*) **Breakthrough.** Raymond Baxter and (*centre*) the *Black Knight* rocket's liquid fuel motor. The motor was shown for the first time on this programme. Behind Raymond Baxter is the factory mock-up of *Black Knight* which was lent by Saunders-Roe for the programme.

FIG. 3. (*Below*) **Prospect Before Us.** An Associated Rediffusion programme broadcast on October 28.

Two important matters discussed by Sir Julian Huxley, F.R.S. (*left*), Aldous Huxley, and Dr Bronowski (*right*) were: (*a*) that man is now living through a biological revolution rather than an atomic age and that he must try to find out more about himself; (*b*) that there is a necessity for real education throughout the world and man must make his brain a more efficient organism.

(*Photograph by David Farrell*)

the best of its kind, lively, critical, and up to date. It dealt with a matter of universal interest and was a stimulating, yet not in any sense acrimonious, programme. Mr McCloy is to be congratulated both for his ideas and their presentation in this whole programme. Your reviewer noted with satisfaction that in this programme the longer items more often occupy about a quarter of an hour. These are undoubtedly far superior in every sense to flashes and snippets.

ITA continue to give us its regular broadcast, "New Horizons", which is effectively a prolonged lecture course given by Dr J. Bronowski. On December 9 a complete half-hour entitled "Smaller Than Atoms" was broadcast. In this, Dr Bronowski attempted the formidable (shall we say impossible) task of explaining to the lay viewer, in half an hour, the meaning of the Quantum Theory. Your reviewer must at the outset maintain that after 25 years of experience in the teaching of the origins of Quantum Theory to undergraduates, he is firmly convinced that the relevant concepts are sufficiently remote from the layman to make it utterly impossible to do anything reasonable in a mere half an hour. Despite the obvious high gifts of exposition possessed by Dr Bronowski and despite the elegant compactness of his presentation, it is certain that all lay viewers must have been bewildered. It was necessary to compare and contrast both wave-propagation and photoelectric emission, and this alone was far too much in the time available.

Perhaps a fair summary of this broadcast would be that it was ideally and admirably suited to sixth-formers who had already taken or were about to take Advanced Level in Physics in the General Certificate of Education. For such viewers there was much to learn and to appreciate, but for others with less accomplishment in physics there was surely bewilderment.

There is no doubt in the mind of your reviewer that unfortunately both ITA and BBC failed to broadcast enough on the subject of the Quantum Theory during 1958. Attention has already been drawn before in these columns to the fact that in 1958 the world of science was celebrating the centenary of the birth of Max Planck, the creator of Quantum Physics (see DISCOVERY, 1958, vol. 19, p. 133). Indeed, a strong plea was registered here that the science programme planners should lay on a full course of programmes to expound the Quantum Theory, comparable with the excellent series put out by the BBC to commemorate the centenary of the appearance of Darwin's classic work on Evolution. Both the origins and the ramifications of Quantum Theory are certainly of sufficient significance to have justified the mounting of a full-scale series, with a number of experts and with detailed experimental illustration. Of course the layman could not understand Complementarity or the Infra-red Catastrophe, but he does understand an atomic explosion, and if it can be made clear to him that control of atomic energy only became possible through our knowledge of quantisation processes, he would probably be interested in the Quantum Theory.

The centenary, alas, has passed, but quanta are still with us and maybe programme planners will yet appreciate the arguments made here.

S. TOLANSKY

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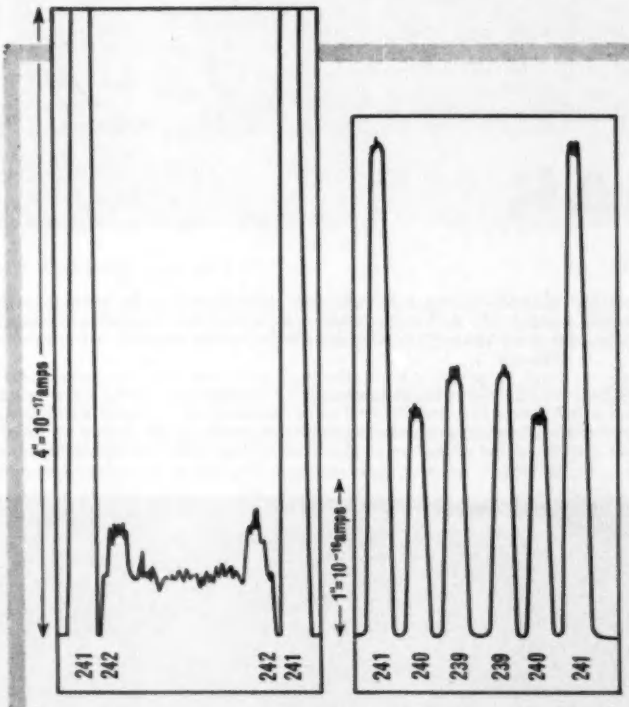

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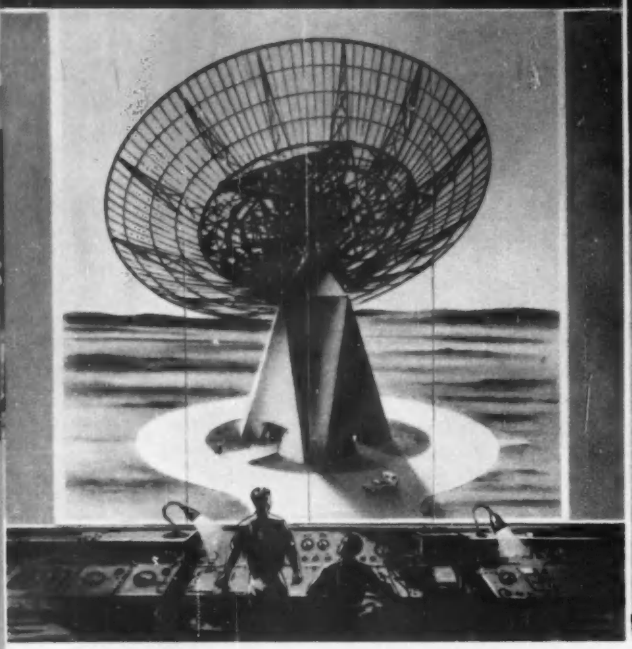

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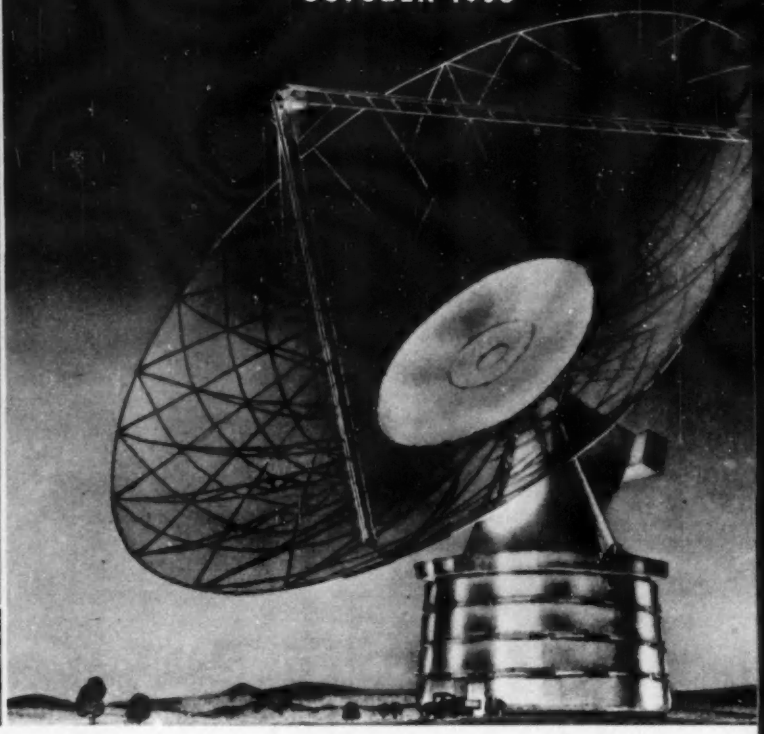


FAR AND NEAR

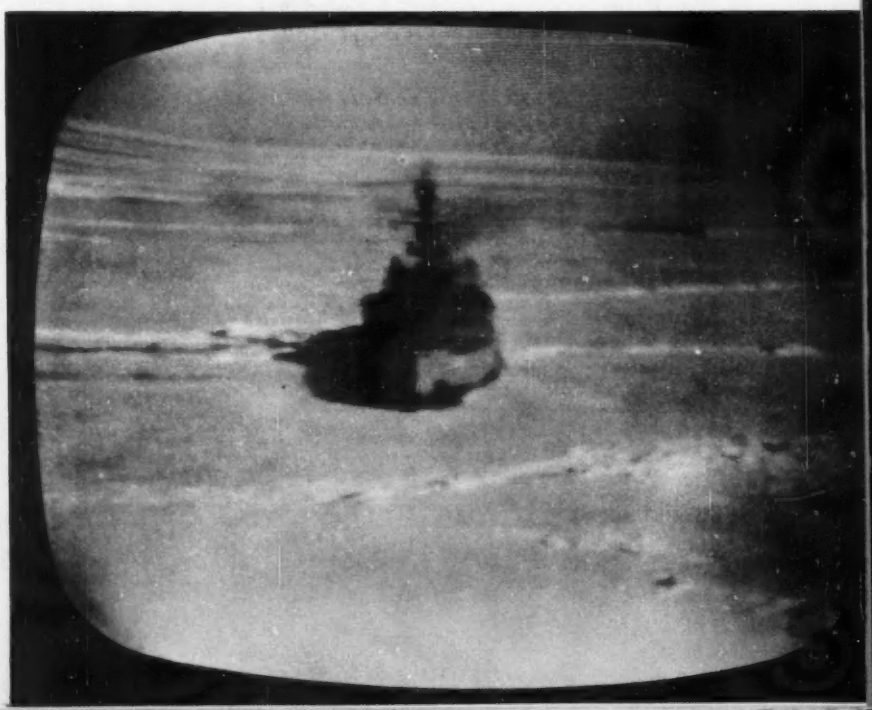
AUSTRALIA'S RADIO-TELESCOPE

A full description and an artist's impression of the plans for Australia's giant radio-telescope were published in DISCOVERY, August 1956, vol. 17, p. 312. Two and a half years later the project is apparently still only in the artist's impression stage, although it was hoped to begin work towards the end of 1958. It seems that the artist has progressed in his design but the scientist is still awaiting his telescope.

The radio-telescope in the northern hemisphere at Jodrell Bank was hardly completed when it proved its outstanding value in tracking artificial satellites. One would have thought that two and a half years between the first announcement of a project and the issue of a second artist's impression could have been more fully occupied for design studies and foundation work. Time should be the essence of this contract if Australia's contribution is to be as great a credit to her engineers as the work of her radio astronomers has been in the past.

TELEVISION AIDS NAVIGATION

A television camera, developed by the United States Navy and Philco Corporation engineers, was mounted in a Navy helicopter and used to send a picture back to the Navy's largest ice-breaker, U.S.S. *Glacier*, showing the best route through the icefields during Arctic operations. The camera image was picked up on two television receivers on board the *Glacier*, where ice conditions were recorded. This television image shows the *Glacier* in an icefield on the way to Thule, Greenland, and was taken as the helicopter aimed the camera in the ship's direction.



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Italian workmen will drill into the rock for a distance of 6450 m. and French workmen—starting the other side—will drill for 5150 m., and they will meet in the centre. The total cost is estimated at 19·5 billion lire.

Photograph (*above*) shows Mont Blanc and the Brenve glacier which will be pierced by the tunnel.

Photograph (*below*) shows two workmen with an Atlas Tiger rock drill. On the left can be seen the 000 (Zero) mark where the drilling is to start.

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Taking photographs inside underground storage tanks containing radioactive waste.

Photograph shows machinists and photographers at the Hanford Atomic Plant mounting a camera on a steel pole to get a complete picture of the inside of a slightly radioactive tank, which only has a 9-in. entrance. The disc at the top is calibrated to assure a 360° sweep of the tank's interior; it also stops radiation escaping while the photographs are being taken. When all the photographs have been taken a composite picture of the inside of the entire tank can be made.

Science in Parliament: November 25–December 18

The last day (December 18) before the Christmas recess saw an interesting Adjournment Debate in the Commons on Government aid for science. An Opposition spokesman stressed the inadequate resources devoted to scientific research. He quoted from the last report of the DSIR the contrast between that department's annual budget of less than £10 million, compared with the value, nearly £10,000 million annually, of production by those industries *not* benefiting directly from defence research. This position might well be aggravated by the lessening of the defence effort which has been a real driving-power behind scientific research generally in recent years. The problem was not one of inadequate Government assistance alone. Industry, which was spending £68 million annually, including defence, must be persuaded to devote still more resources to research, a desirable target for a manufacturing industry being around 1% of its turnover. The Government spokesman replied by emphasising what was already being done: the Government would repeat their earlier experiment of financing the DSIR on a five-year basis with expenditure rising from £36 million for the current quinquennium to £61 million for the next; increased grants to research associations to be matched by those from industry were also planned; the number of students in receipt of DSIR grants would be doubled over the next five years, and further expansion of university and technical college buildings and manpower was envisaged.

It was, however, in the Lords that an event of special interest took place, for on December 16 the Nuclear Installations (Licensing and Insurance) Bill, introduced in the Lords earlier in the session, received its third reading. Broadly, the Bill has two main features: first, to protect the public by imposing under licence safety controls on the design, operation, and maintenance of nuclear reactors other than those of the Atomic Energy Authority and Government departments; second, to ensure that anyone suffering injury or damage could claim compensation, as a right and without proof of negligence, from the licensees, who would be required to take out insurance cover for £5 million. This right to compensation extends to reactors belonging to the Atomic Energy Authority and to Government departments, though these are not insured in the strict sense, and where it would be absolute in amount. The Opposition, concerned that a big extension of private enterprise in the nuclear power field might be envisaged, directed part of their suspicions to the basic purpose of the Bill: the Government, while agreeing that private installations would have to be licensed, held that in the immediate future the Electricity Board's power-stations would be primarily involved. More specific was the debate over the time-lag during which a claim could be entertained. Originally this was fixed at ten years after an incident. However, after argument to the effect that many illnesses took more than ten years to manifest themselves, the Government agreed to entertain claims for up to thirty years, with a proviso that both claims made after ten years, and all claims in excess of £5 million would not be met out of insurance cover. They would be paid by the licensee, and reimbursed out of public funds after appropriate Parliamentary approval. While welcoming this concession, the Opposition nonetheless divided the House on the need for having any time limit, arguing that in the present state of knowledge, one could not write any specific period into an act of Parliament. They also maintained that a limit of £5 million might well prove unrealistic and that there should be a right to compensation from public funds, for example on a similar basis to war-damage claims, without the uncertain procedure, in the event of excess claims, of a report to Parliament.

Though it is not unprecedented for legislation to be introduced in the Lords, it is unusual for a Bill of this importance and complexity. The Commons will doubtless scrutinise it carefully, but their Lordships have acquitted themselves well in one of the first debates of this nuclear age.

FAR AND NEAR—continued

"Kunststoffe '59"

The Third "Kunststoffe '59" (International Fair of the Plastics Industry) will be held in Düsseldorf from October 17 to 25, 1959. Compared to its predecessing events, the Trade Fair will be international in all aspects, thus foreign participation will be extended to include raw materials and finished goods.

The organisers are Chemie-Wirtschaftsförderungs-Gesellschaft mbH. at Bonn and Frankfurt/Main, with the co-operation of Arbeitsgemeinschaft Deutsche Kunststoffe-Industrie (AKI), Frankfurt/Main, Fachgemeinschaft Maschinen für die Verarbeitung von Gummi und plastischen Massen im VDMA, Hannover, Fachabteilung Schnitt- und Stanzwerkzeuge, einschl. Werkzeuge für Kunststoffverarbeitung in der Fachgemeinschaft Präzisionswerkzeuge im VDMA, Frankfurt/Main. Publicity, organisation and technical management are being handled by Nordwestdeutsche Ausstellungs-Gesellschaft mbH. (NOWEA), Düsseldorf.

Provisional reservations of space made by approximately 150 firms in W. Germany and elsewhere covering an area of nearly 6500 sq. m. have been made already thus showing the importance which is attached to the 1959 Plastics Fair.

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MICROBIOLOGIST: DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH. Pensionable post as Principal Scientific Officer at Water Pollution Research Laboratory, Stevenage, Herts., for man or woman at least 31 on 1/1/59 for research on microbiological problems arising from work on pollution of rivers and treatment of sewage and industrial wastes. Qualifications normally First or Second Class Honours Degree, (*a*) either in Bacteriology or Microbiology, or (*b*) including Chemistry and Biology, followed by post-graduate Diploma in Bacteriology. Salary scale (men) £1370–£1950. Starting pay may be above minimum. Promotion prospects. Local house or flat can usually be rented. Write Civil Service Commission, 17 North Audley Street, London, W.1, for application form, quoting S4921/59. Closing date March 3, 1959.

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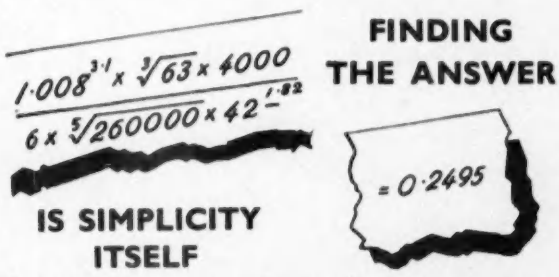

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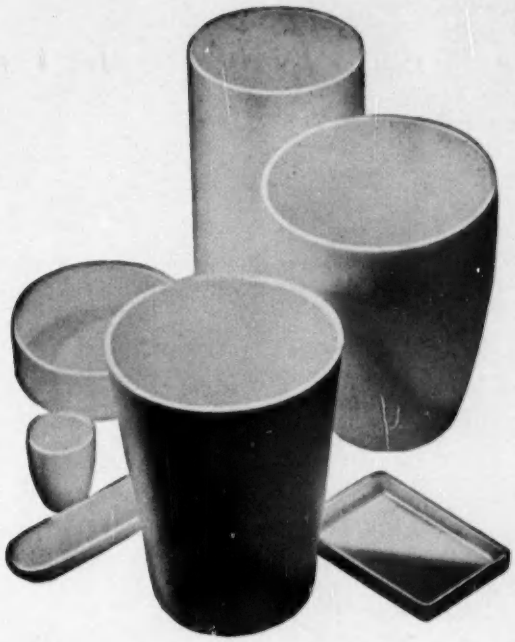

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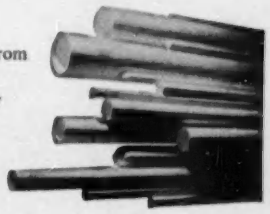

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